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# PREFACE

In the present volume various studies from the psychological laboratories of the University of Iowa are offered for publication and criticism. In somewhat condensed form most of them are derived from theses presented in partial fulfillment of the advanced degrees. They continue for the most part researches in the field of the psychology of music, a subject which has been investigated for the past three decades in this laboratory. One study comes out of the psychological clinic and makes a considerable advance in the direction of a more plausible interpretation of stuttering. Another paper emanates from a previous study on emotion and offers a qualitative and quantitative description of one of the more subtle affective processes. Still another article makes a distinct contribution toward the problem of training in the use of the vibrato. It not only has a systematic bearing on the interpretation of this auditory perception but also is of practical value in the development of artistic singing. Two of the studies furnish further data for interpreting the results of the Seashore tests of musical talent and thus give them a still more substantial scientific status. One of the most interesting studies involves tonal changes that are made in the speaking voice, approximating some of the intervals found in music.

It is a pleasant task that has come to the editor in the preparation of the manuscripts. All of the authors have coöperated in a very friendly fashion with his desire to make each article conform to the standards of scientific style and arrangement. He wishes to acknowledge here his indebtedness not only to these authors concerned but also to several of his colleagues and their assistants who have furnished material aid in the technical procedures and with apparatus in the laboratory. Science today demands more and more the expert coöperation and mutual assistance of men in the various fields of research.

The editor wishes again to express his deep appreciation of the kindly help which Dean Carl E. Seashore has readily and expertly given him in the preparation of the manuscripts. Several of them are the work of students whose research Dean Seashore has directed.

THE EDITOR

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# DISTURBANCES IN BREATHING DURING STUTTERING [1]

BY

HAROLD RAY FOSSLER

*Introduction; selection and development of the problems; pattern problem and method; apparatus; observers; pattern problem, results; variability problem, method; variability problem, summary of results; descriptive problem, description of typical curve forms; beginning; course; end; interruptions; descriptive problem, summary of observations on typical curves; descriptive problem, general description of plates; summary of the description of plates; general summary; bibliography.*

*Introduction.* Stuttering,[2] being one of those human afflictions, which by virtue of its nature cannot be concealed except by an intolerable silence, has always been open to general observation and interest, so that in spite of its comparative rarity it is hardly unknown to anyone. The great variety of its manifestations, together with its stubborn resistance to remedial measures, have made it one of those problems upon which much has been written, not only by specialists but also by laymen. Although considerable work has been done to devise effective methods of treatment, a systematic experimental inquiry into the problem of the nature, causation, and treatment of stuttering, is a matter of comparatively recent history.

In dealing with this problem of stuttering it may be said that emphasis has been given from time to time to three general aspects, namely, the anatomical, the physiological, and the psychological. In the earlier days the anatomical aspect was stressed when it was noted that certain parts of the speech mechanism failed to perform their function. Surgical operations were frequently performed to remedy this defect. The tongue, for example, was shortened by cutting out a transverse slice and lengthened by cutting the lingual frenum. The surgical

[1] This study was done under the direction of Professor Lee Edward Travis.

[2] The term stuttering is used throughout to include stuttering and stammering.

method of treatment was carried to such alarming extremes that it soon fell into disrepute, for while many were maimed, few were cured. Attention came to be directed to the physiological aspect of the problem, since after all, experience seemed to show that the trouble was not one of diseased parts but one of badly coördinated parts. It was held that proper training would develop the desired coördination. Out of this grew the extensive organization of all sorts of exercises to strengthen weaknesses and to harmonize the different elements. This method, at least, left the organism intact so that it might be further trained if success were not forthcoming. But it was soon suggested that the disturbance also involved the more subtle mental factor. The functional disturbance was attributed to some peculiar "mental twist," the correction of which, it was maintained, would restore the stutterer to normality. As a consequence of this, stutterers have been exercised in making extensive reports upon their mental states which seemed to be related to stuttering. They have been subjected to hypnotic suggestion and to psychoanalytic therapy, all in the interest of discovering and correcting some mental abnormality which was regarded as responsible for the trouble. A more complete account of the history and development of methods of treatment and theoretical points of view may be found by referring to *Bluemel* (1, 2), *Fletcher* (6), and *Wallin* (12). The psychoanalytic point of view is presented by *Coriat* (4) and *Eder* (5).

The experimental study of stuttering is a field that has been somewhat neglected because its appeal is largely to one who has a restricted interest in this phase of speech disorder but not to the general psychologist or physician. The work which has been done has been of the pioneering sort that aims to blaze trails and indicate the directions which later research may profitably follow.

One of the earlier experimenters was *Halle* (8), who reported: (1) tonic and clonic spasms of the diaphragm; (2) alterations of the breathing curves before and after speaking due to psychical causes; (3) poor economy of breathing; (4) speaking on inspiration; and (5) withholding breath after speaking.

*Ten Cate* (10) was the first to make simultaneous curves of thoracic and abdominal breathing. He observed that (1) stutterers have normal chest expansion and average lung capacity, (2) expiration is shorter in stutterers than in normals, (3) the "rest" breathing of stutterers is like the "rest" breathing of normals, (4) there is always a disturbance of breathing in speech defects, (5) the normal anachronism of speech breathing is broken up in stuttering, (6) inspiration curves are steeper in stutterers than in normals, and (7) the breathing rate is faster in stutterers.

*Gutzmann* (7), whose extended studies in speech pathology are well known, described what he considered to be primary and secondary abnormalities. Under the former were included too frequent inspiration, prior postponement, and spasms both tonic and clonic. Under the latter, mention was made of breathing spasms depending upon spasms of the organs of articulation.

*Fletcher* (6), one of the earliest investigators in this country, comes to the following conclusions: (1) stutterers possess no peculiarity of breathing that is unrelated to the function of speaking; (2) there are as many varieties of breathing peculiarities among stutterers as there are varieties of stuttering; (3) the average and the mean variation of breathing intervals are greater during stuttering than during normal speech in the same person; (4) there is evidence of a rhythmic character in stuttering in that both inspiration and expiration are withheld: in one case speech is held up and in the other it is forced on comparatively empty lungs; (5) there may be a complete breaking up of the normal rhythm; (6) inhalation and exhalation may be mutually inhibited; (7) there is an approximate synchronism in costal and abdominal breathing; and (8) there are some stereotyped patterns for individual stutterers.

*Robbins* (9), in a study of shock and stuttering, used one thoracic pneumograph placed under the armpits as a check to other observations. It enabled him to compare the breathing of stutterers and normals while reading the same passage. As the result of this study he concluded: (1) all stutterers breathe

abnormally while stuttering, and (2) every stutterer has a characteristic form of breathing while stuttering.

*Travis* (11), who reports some of the most recent studies in this field, summarizes his conclusions thus:

> "Records of normal speech show an integration of the breathing mechanism, which exhibits the following characteristics: (1) a fairly close correspondence between the thoracic and abdominal breathing; (2) a relatively greater number of laryngeal than of breathing movements; (3) relatively complete independence between vertical movements of the larynx and movement of breathing; (4) an evident rhythm of breathing of the vertical movements of the larynx, and of the changes in breath pressure; (5) a disproportionate increase in duration of expiration during speech; and (6) the presentation by the abdomen of small in-and-out movements at a rate varying from 5 to 7 a second.
>
> "Our records of stuttering show a dysintegration of certain of the speech units which apparent at various times in the following ways: (1) a complete antagonism between the action of the thorax and that of the abdomen; (2) marked synchronism between the movements of the larynx and those of the various units of the breathing apparatus; (3) marked prolongation of inspiration; (4) large vertical movements of the larynx during inspiration; (5) clonic and tonic spasms of the various muscles of speech production; and (6) the apparent introduction of a new tremor rate in the abdomen."

The literature on stuttering reveals that at one time or another, most, if not all, the various manifestations of stuttering have been regarded by someone as essential to the comprehension of the nature of stuttering and therefore as significant guides to its cure. The articulatory aspect of the problem has not been neglected in this regard. As *Fletcher* pointed out, some writers have held to the consonants as the real trouble makers, others have emphasized the vowels as the chief offenders, while still others more impartial and comprehensive, have included both. The same point has been made with reference to the position of the vowels and consonants. *Fletcher* adds that it would probably be more nearly correct to look to the syllable than to any of its components. *Bryngleson* (3), in a thesis on the articulatory difficulties of stutterers, worked out in our laboratory, seems to have been the first to make a systematic attempt to settle the point. His main conclusions are: (1) Ten per cent of the thirteen cases had difficulty with medials or sounds other than the initials of the word, (2) stutterers had difficulty with both consonants and vowels, (3) stuttering occurred in both

social and non-social situations, (4) there was marked inconsistency as to when, on what sound, and how stuttering occurred, (5) different subjects do not all have equal trouble with the same sounds, the number of difficulties varying from person to person and from time to time, (6) stuttering occurs on both initial vowels and consonants, (7) it seems impossible to arrange the sounds of the alphabet in any kind of order from the standpoint of effectiveness in producing stuttering, (8) there is no consistency in the repetitions, words, phrases, syllables, or sounds being repeated and varying from person to person and from time to time, (9) the speech organs of stutterers function as normally as those of normals except when stuttering is in progress, and (10) substitutions show the same inconsistency as repetitions.

*Selection and development of the problem.* This particular study is one of a group of symptomatological studies of stuttering being carried on at the present time in the laboratory of the speech clinic. It includes three closely interrelated minor problems, the development of which will be traced at this point.

Since *Bryngleson* found far-reaching inconsistency in the articulatory disturbances where more or less uniformity had been suggested, the question arose as to whether this same inconsistency would be manifested in the breathing and laryngeal movements during stuttering. *Fletcher* reported recurrent patterns in the breathing curves of stutterers which were characteristic of individual stutterers. These recurrent patterns might therefore be related to some articulatory patterns in spite of the general inconsistency indicated by *Bryngleson*, since every stutterer seemed to have greater difficulty with certain combinations of sounds than with others. Hence, the patterns might be associated with the more difficult ones. The discovery of any such diagnostic patterns would not only have far-reaching significance for the general interpretation of stuttering but would also have hopeful clinical significance.

In order to state the problem clearly and at the same time to indicate the guiding hypothesis, specific questions are presented which the research was designed to answer.

(1) Are there any observable, typical, recurrent patterns revealed by the pneumographs and laryngograph?

(2) If there be such patterns may they be definitely associated with the production of any particular sound or group of sounds?

(3) May they be associated with some general articulatory defect which is independent of the production of any sound or group of sounds?

(4) Are they consistent or relatively variable in the same individual?

(5) Are they common to different individuals?

Some of the earlier studies suggested that stuttering introduces marked fluctuations into the breathing curves. These observations of fluctuations were confirmed in the progress of the study of patterns. Since variability in the breathing curves includes many factors, the great demand for quantitative results led immediately to the question as to what factors of this problem might be submitted to exact quantitative study and what factors would have to be left to a supplementary qualitative description. Inquiry revealed that the factors of amplitude and time could be very satisfactorily reduced to quantitative determination.

The study of fluctuations or variability involved measurement of both inspiration and expiration with regard to amplitude and time during free, unemotional, propositional speech and during "rest" breathing. This part of the study aimed, therefore, to answer the general questions: (1) how do stutterers and normals compare with each other in regard to the factors of amplitude and time of inspiration and expiration during free, unemotional, propositional speech, and (2) how do stutterers and normals compare with each other in regard to the factor of time of inspiration and expiration during rest breathing?

We recognized, however, that a careful analytical qualitative description was necessary in an adequate treatment of variability in breathing curves, since there are important aspects of variability not described quantitatively. The study of patterns, moreover, indicated the necessity of a qualitative description

of curve-types found in that study. We were thus led naturally to the third problem, namely, that of the qualitative description of breathing curves, which was designed to complete the results of the study of patterns and the quantitative study of variability.

*Pattern problems and method.* Different workers have used different methods of eliciting stuttering. *Fletcher,* for example, gave his subjects material to read, asked them to relate some experience, or if these failed, he introduced strangers into the room in order that the consequent embarrassment might bring out the stuttering. *Robbins* used various methods of shocking the subject, such as the introduction of sudden, loud noises, or the presentation of strange objects. The obvious purpose was to induce stuttering. The specific methods by which this was accomplished were not regarded as especially significant. *Fletcher,* in discussing his method says, " Attention must be called to the fact that, while in these experiments methods of registration must remain constant, the stimulus used to provoke stuttering, which is the phenomenon to be studied, cannot remain constant for the obvious reasons that the same stimulus will not produce stuttering in all individuals, and that the same stimulus will not produce constant effects in the same individual."

All writers agree that there is a close relation between stuttering and emotional disturbances and experimenters have availed themselves of this knowledge, as we have seen, when stuttering was not forthcoming, by applying some emotion-producing stimulus which would bring it out. But it has also been pointed out by *Fletcher, Robbins,* and others that slight emotional disturbances are registered in the breathing mechanism along with changes in the heart-rate and general vaso-motor changes, consequently, when one is observing stuttering produced by some obvious emotional shock, he is not sure whether the changes in the breathing are due to the shock or to the stuttering. Since at the outset there was a fair presumption that the patterns for which search was being made might not be found, it is clear that every precaution must be taken lest they be obscured by any factors not under control. Conditions must be arranged that are most favorable to their appearance so that any failure

to appear will not be due to any defective technique within the instrumental possibilities. An emotional change due to the application of shocking stimuli might easily be such an obscuring factor and consequently was not used in this study. Preliminary study showed, moreover, that reading matter, whether prose or poetry, was not strictly comparable to free, unemotional, propositional speech, and that the problem of stuttering as it was manifested with different types of reading matter was of sufficient magnitude and importance to warrant separate investigation.

We decided, therefore, to reduce the conditions of the investigation to their lowest terms so far as the emotional factor was concerned and to limit the study to free, unemotional, propositional speech. The severe cases of stuttering provided plenty of material under these circumstances and the results were then referable to constant conditions. The same precautions which were taken as far as possible to exclude emotional factors were extended to apply to the physical comfort and peace of mind of *O*. The room was therefore comfortably heated and well lighted, the *O*s were directed to assume a natural and comfortable posture, and the whole atmosphere was designed to suggest rest and quiet. A long preliminary practice period was given, moreover, in order to provide complete adaptation to the experimental situation, and to reduce self-consciousness to a minimum. At the beginning, as is usual with tests of any kind, the *O*s were very much interested in comparing their records with the records of others. They wanted to make a good showing. Such an active interest would introduce a serious error since it would have led to a conscious modification of breathing. The practice period was therefore also necessary to inculcate an attitude of discreet unconcern as to the results.

The assumption that all emotion-producing factors were eliminated was checked by direct observation by *E,* by direct questioning of *O* on this point, and by the general consistency of *O*'s overt behavior, his statements, and his records taken together. *E* was constantly on the alert for signs of annoyance or discomfort. Frequent inquiry was made as to the state of *O*. When all points agreed the assumption was deemed justified.

In order that any specific patterns might be the more easily detected under favorable circumstances, an innovation was introduced. We found that a pneumograph placed just below the lower point of the sternum was more sensitive than one placed on the upper chest or upon the abdomen. We determined to use all three instruments, since these would provide a more complete record of the breathing units than had hitherto been provided by only one or two pneumographs.

The general procedure may be briefly indicated. All instruments were carefully adjusted and tested on all occasions before any records were taken. The outer clothing of *O* was removed and the instruments were put in place. The laryngograph was securely adjusted upon the thyroid cartilage. The upper-chest pneumograph was placed in the middle of the chest at the level of the armpits where the fastening cord was passed around the trunk. The lower-chest pneumograph was placed just below the lower end of the sternum. The abdominal pneumograph was placed over the umbilicus when the subject was seated ready for recording. *O* was seated in a chair in a natural, comfortable position. He sat half facing *E* and as close as convenient in order that lip movements might be closely observed and articulations distinctly heard. In order that *O* would understand the operations of *E,* the general run of the experiment and the method of recording were explained. All questions of *O* were answered as satisfactorily as possible.

*O* was asked to refrain from all unnecessary movements. He was directed not to obscure or conceal the word upon which he might have difficulty by such devices as shifting to another word, *e.g.,* a synonym, or avoiding the word altogether, but to continue with the difficulty to the end, since, otherwise, *E* would be left without a cue to indicate the word that was giving trouble. This point needed considerable emphasis since several of the *O*s were in the habit of using these roundabout methods of expression. Direct questioning might have been employed to reveal the troublesome word but such interruptions were very disturbing, and, therefore, were avoided.

It was necessary to check such accessory movements as sighing,

yawning, sniffing, coughing, sneezing, clearing the throat, and short laughs since all these introduced disturbances into the records.

The following explicit directions which were given to *O* in the preliminary trials, were discontinued after he became thoroughly famliar with the procedure:

"We are now going to take a record of your breathing and of the movements of your larynx while you are talking. We want you to talk freely without interruption just as if you were relating some very ordinary experience to a friend. You may talk about anything you want to, such as some trip you took, some book you read, some play you saw, some incident you noted during the day or some early boyhood experience you remember. Anything will do. You may talk sense or nonsense, the main thing is to talk and to do it just as naturally as possible. The best way to do this is not to worry about it at all. You may use any language you want to. Just talk in your own way. Now talk right along and be natural. Don't worry about anything. You will do it all right. You have plenty of time, so be comfortable. Go ahead."

An electric marker which *E* operated by means of a key was used to indicate when stuttering took place. When stuttering began the key was pressed so that the marker line showed a depression. When stuttering ceased the key was released so that the marker line returned to its former level. Thus the stuttering interval was indicated by a depression in the marker line. In addition to this *E* wrote down the word which gave trouble, on the margin of the record beside the corresponding depression in the marker line.

This method of recording was very difficult until considerable practice made it possible to catch and to record a large number of the stuttering intervals with considerable accuracy. In some cases the periods of stuttering were so frequent and the number of words giving difficulty was so great that only a part of them could be recorded. Even after long practice, however, we recognize that the method was not perfect so far as temporal accuracy is concerned, although the degree of accuracy was thoroughly satisfactory for this experiment. We thought for a time that failure to discover the patterns we were looking for might be due to defects in the method, but further investigation relieved us on that point.

*Apparatus.* A kymograph set-up was used in this study. The large drum was 9½ in. in diameter and 12½ in. high. The

small drum was 3 in. in diameter and 12½ in. high. The instrument could be adjusted to take a length of paper up to 2.75 m. The power was furnished by a small motor which sustained practically a uniform speed. The speed at which records were taken required 7.5 min. to run a full length of paper.

The recording instruments consisted of four Jaquet tambours, one Jaquet chronometer, one Boulitte laryngograph, two Boulitte pneumographs, one Sumner pneumograph, and one electric marker. A double-cup Boulitte pneumograph was used for the upper-chest breathing, a Sumner pneumograph for the lower-chest breathing, and a cylindrical type Boulitte pneumograph for the abdominal breathing.

*Observers.* Thirteen stutterers and thirteen normal individuals, all males, were used in this study. Of the stutterers, ten were college freshmen, one was a high school senior, one was an eighth grade student, and one was an agriculturist, 30 years of age. All of the normal individuals were college men of senior or graduate standing.

*Pattern problem; results.* In order to determine at the outset whether the stutterers used in this study were comparable to those used by *Bryngleson* in his study, on the point of general inconsistency in articulatory patterns, 40 records were taken of each of the severe stutterers (seven cases) and seven records of each of the mild stutterers (six cases). In recording the words with which difficulty was experienced by the severe stutterers, *E* was pushed to the limit of his writing speed most of the time. The extent of the stuttering vocabulary was considerable. In order to compile an extensive vocabulary used by the mild stutterers, either a vast number of records or some more productive method of inducing stuttering would have been required. We did not think it desirable to do either. We considered it legitimate to allow the heavy burden of proof to fall upon those severe stutterers, since patterns should be developed in them, if anywhere, in their greatest variety and in their most stable forms. If articulatory disturbances are ever able to impress themselves upon the breathing apparatus that fact should be observable in severe stutterers.

We should, therefore, be in a position to report specific patterns if any such were to be observed, for the reason that we have gathered extensive records from sufficient cases, and we have fortified these records as far as possible against the disturbances of any patterns that might be expressed.

The questions at the outset may now be answered:

(1) There are some observable, typical, recurrent patterns revealed by the pneumographs and the laryngograph.

(2) They are not definitely associated with the attempts at production of any particular sound or group of sounds. They are, in this sense, general, not specific patterns.

(3) In a few cases they have been associated with defects in the articulatory apparatus but were independent of the production of any sound or group of sounds.

(4) A few patterns have been found characteristic of individuals.

(5) A few patterns have been found common to more than one individual.

It is thus apparent that, although various types of patterns were found, none of them could be definitely connected with any specific articulatory trouble that had to do with the production of any particular sound or group of sounds.

*Variability problem; method.* The problem of variability has been touched upon by some previous investigators in certain observations involving the time element in breathing. *Ten Cate* pointed out that inspiration curves were steeper in stutterers than in normals. He declared that expiration is longer in stutterers than in normals. *Fletcher* reported that the mean variation is greater for intervals in which stuttering occurred than in those free from stuttering in the same individual. He noted also that in rest breathing the inspiration and expiration are approximately equal.

In this problem variability in both rest breathing and speech breathing was considered. In speech breathing four variables were considered, namely, amplitude of inspiration and of expiration and time of inspiration and of expiration. In rest breathing only the time of inspiration and of expiration were considered,

since the study of speech breathing did not reveal any significant difference between stutterers and normals relative to amplitude.

It will help in the understanding of the method used to consider briefly *Fletcher's* procedure and to point out some difficulties that had to be met.

In order to show that stuttering tended to lengthen the expiration time, *Fletcher* selected expirations in which stuttering occurred and compared them with expirations free from stuttering in the same individual. On the basis of this comparison he reported that the mean variation is greater in the stuttering expirations than in the free expirations. In order to avoid introducing serious errors into the measurements under this plan it was necessary to be very precise in the determination of the beginning and the end of any paroxysm of stuttering, since stuttering that occurred near the extremes of an interval might easily have been displaced to an adjacent interval. The effects of a paroxysm of stuttering extended to several succeeding intervals in which no stuttering may have occurred. In such a case these effects could not be evaluated. The amount and severity of stuttering may vary greatly from interval to interval and from person to person. Therefore every disturbance was noted. Some individuals stuttered almost continuously so that undisturbed intervals would rarely have occurred. In such cases a comparison would have been difficult to make and some of the best examples of stuttering could hardly have been used at all.

Experience gained in the study of patterns indicated the seriousness of these points. We found that the precision necessary to determine both the beginning and the end of a stuttering interval with a high degree of accuracy was so extremely difficult to attain with available technique that the results would be open to attack on this score. If perseverating effects were to be evaluated, moreover, it would be necessary to consider a large number of consecutive intervals, otherwise the effect would be equivalent to an uncontrolled emotional disturbance. In some cases we could not catch all disturbances for registration. Finally, we found it very desirable to use stutterers who stuttered almost continuously.

The seriousness of these factors was obviated by another procedure. If long records, which were free from all accessory disturbances, were taken, in which a large number of consecutive measurements could be made, not only could we make comparisons between different stutterers, but we could also compare stutterers with normals in regard to the length of expiration and upon other points as well. This procedure avoided the difficulties of the other method and at the same time, greatly extended the range of its application.

Such a procedure was precisely that which was followed in the study of patterns, consequently we decided to continue it in this study. The advantages of so doing are obvious. The *Os* were already well trained in this procedure and were thoroughly accustomed to the experimental situation. *E* was also trained to the vigilance required to rule out disturbing factors. The conditions, therefore, were excellent for a careful study of variability.

The same stutterers who served in the pattern study served also in this study. An equal number of normal male cases were taken from our laboratory group and from a class in speech pathology.

In order to obtain records under our rigorous experimental requirements that were as free as possible from all disturbances and on which one hundred consecutive measurements could be made, we had to take a very large number of records. Measurements were made only on such selected records.

The amplitude of an inspiration was measured from the highest point at the beginning of a downward stroke to the lowest point at the end of the stroke. The amplitude of the following expiration was measured from this same lowest point, or beginning, of the expiration to the highest point, or end, of the expiration. The highest points may then be considered either as beginnings of inspirations or as ends of expirations depending upon which measurement is desired. In the same way the lowest points may be thought of as ends of inspirations or beginnings of expirations.

It will be remembered that the recording arm of the tambour was a lever and that in its vertical movements it did not describe

a straight line but the arc of a circle whose radius was equal to the length of the recording arm. The stylus did not always fluctuate within the same portion of its arc but sometimes it swung to a much higher or lower level than at other times, depending upon such factors as variations in the amount of unused air in the lungs and changes in the depth of breathing.

Measurements of amplitude were taken to the nearest millimeter on a line perpendicular to the base line made by the marker. The curvature of the downward stroke was negligible in the measurement of vertical distance when this scale of measurement was used.

The measurement of the distance of lateral movement was also taken to the nearest millimeter. A millimeter indicates approximately one-sixth of a second of time. Here, however, it was necessary to take very careful account of the curvature in both the upward and downward strokes.

In order to measure the time of an inspiration or an expiration we had to measure the distance of the lateral movement of the kymograph paper. In order to measure this movement we took account of the curvature of the stroke of the stylus as it described its up and downward movements. A device to compensate for this curvature was used in making the measurements. A rectangular sheet of celluloid 8 in. x 10 in. had a segment cut out at one end so that the curved edge of the sheet coincided with the arc described by the vertical movements of the stylus. The movement of the paper was to the left, hence, in reading the records, the cut-out side of the celluloid sheet was to the right.

Before a record was made, all instruments were carefully adjusted and orientation marks described. These were simply made by allowing the subject to breathe deeply so that the movements of the styli might be recorded before the drum was set in motion. In case any instrument was changed a new orientation mark was made for this instrument. These orientation marks were necessary to adjust the celluloid sheet to the proper distance from the base line for reading.

The record sheet was stretched out flat upon a long table with the beginning at the left. The celluloid reading sheet was placed

upon the record with its lower edge parallel to the base line of the record so that the orientation mark on the curve to be measured coincided with the curved edge of the reading sheet throughout its entire length. The distance from the lower edge of the sheet to the base line of the record was carefully measured and marked off so that a long, straight-edged, thin strip of wood might be laid down upon the record with the edge parallel to the base line and at the measured distance from it. When this was fastened in place, the reading sheet could be slipped along the lower edge upon the strip which kept it always in the correct position. Where thousands of measurements had to be made, such an arrangement was very convenient.

If the stroke of the stylus coincided with the edge of the reading sheet when the drum is not in motion, it will shift its position as soon as the drum is set in motion. Thus if the sheet be placed so that its edge just touches the highest point, or beginning, of an inspiration curve, the lowest point, or end, of the inspiration curve will be seen to fall to the right by a certain distance, indicating the time taken for the inspiration. This distance should be measured from the point on the curve to the arc of the sheet parallel to the base. Likewise in measuring the time of an expiration, the sheet was placed so that the curved edge just touched the lowest point, or beginning, of the expiration curve. Then the distance from the highest point, or end, of the expiration to the arc of the sheet parallel to the base, indicated the time of expiration. This device when so used compensated for the curvature of the strokes of the stylus regardless of the amplitude of the relative position of the stroke in its arc.

Our study of patterns showed that the lower chest pneumograph recorded more minute changes in breathing than either of the other pneumographs. Since variability in breathing should thus be manifested most favorably in the lower chest curves, all measurements in this study were made on the lower chest curve. The three breathing curves were approximately synchronized; the same general relation will therefore hold with respect to the other curves.

In dealing with the problem of variability, three statistical measures were used. The arithmetic mean or average was used as a measure of central tendency. The standard deviation was used as a measure of dispersion. *Pearson's* coefficient of variation was used as a measure of relative variability since it takes account both of the central tendency and of the dispersion. The formula for this coefficient is $V = \frac{100 \text{ S. D.}}{\text{average}}$. This measure makes it possible to compare one individual with another and one group with another, since all the coefficients of variation are comparable one with another. The results obtained by the use of this coefficient will be comparable also with results obtained with other instruments, since the relative and not the absolute measures are involved. The value of this coefficient is further seen in the study of amplitude where such variations as length of stylus levers, sensitiveness of tambours and pneumographs, chest expansion, girth and depth of breathing, make it impossible to compare absolute measures.

In the study of time both the absolute measures and the coefficient of variability were used.

TABLE I. *Comparison between time of inspiration and time of expiration in stutterers with reference to A. M., S. D., and C. V.*[3]

| | Inspiration | | | Expiration | | |
|---|---|---|---|---|---|---|
| *O* | A. M. | S. D. | C. V. | A. M. | S. D. | C. V. |
| Swe. | 4.57 | 1.39 | 30.41 | 20.16 | 7.77 | 38.5 |
| Koe. | 3.48 | 1.31 | 37.64 | 11.25 | 5.64 | 50.1 |
| Koh. | 3.64 | .90 | 25.00 | 21.39 | 9.66 | 44.6 |
| Isa. | 3.02 | 1.53 | 50.6 | 19.17 | 9.51 | 49.6 |
| Mad. | 4.16 | 2.27 | 54.5 | 13.17 | 7.20 | 50.8 |
| Hor. | 3.81 | 1.58 | 41.5 | 12.36 | 5.40 | 43.7 |
| Bem. | 6.33 | 3.57 | 56.3 | 14.34 | 10.95 | 76.0 |
| Joh. | 6.91 | 3.22 | 46.6 | 21.06 | 13.05 | 61.9 |
| Bel. | 3.04 | 1.16 | 38.1 | 39.15 | 19.23 | 49.1 |
| Tri. | 3.24 | 1.07 | 30.3 | 19.59 | 6.96 | 35.5 |
| Geb. | 4.41 | 1.47 | 33.3 | 16.05 | 6.66 | 41.5 |
| Han. | 4.1 | 1.50 | 36.6 | 13.02 | 8.19 | 62.4 |
| Nix. | 3.03 | 1.81 | 59.3 | 15.78 | 9.66 | 60.5 |
| *Average* | 4.13 | 1.75 | 41.55 | 18.2 | 9.22 | 51.1 |

[3] In all tables the arithmetic mean will be represented by the abbreviation, A. M.; the standard deviation by S. D.; and the coefficient of variation by C. V.

TABLE II. *Comparison between time of inspiration and time of expiration in normals, with reference to A. M., S. D., and C. V.*

| | Inspiration | | | Expiration | | |
|---|---|---|---|---|---|---|
| *O* | A. M. | A. D. | C. V. | A. M. | A. D. | C. V. |
| Rey. | 4.39 | 1.28 | 29.1 | 20.68 | 8.94 | 43.0 |
| Hun. | 2.96 | .90 | 30.3 | 29.76 | 8.94 | 30.0 |
| Tra. | 4.77 | 1.45 | 30.4 | 16.29 | 6.36 | 39.0 |
| Bro. | 3.56 | .97 | 27.2 | 18.39 | 7.26 | 39.4 |
| Cha. | 3.72 | 1.37 | 36.5 | 16.47 | 7.12 | 43.2 |
| Her. | 4.03 | 1.40 | 34.7 | 15.06 | 7.05 | 46.8 |
| Fag. | 3.91 | 1.46 | 37.3 | 13.26 | 6.75 | 50.9 |
| Dun. | 3.72 | 1.96 | 52.6 | 16.50 | 7.50 | 45.4 |
| Fau. | 3.88 | 1.08 | 20.1 | 18.12 | 6.60 | 36.4 |
| Hel. | 3.58 | 1.18 | 32.9 | 16.95 | 6.84 | 40.3 |
| Smi. | 3.53 | 1.37 | 38.8 | 10.17 | 4.59 | 45.1 |
| Fos. | 5.67 | .88 | 15.5 | 40.92 | 13.78 | 32.7 |
| Bek. | 3.6 | 1.16 | 32.2 | 31.62 | 9.63 | 30.4 |
| *Average* | 3.95 | 1.27 | 32.12 | 20.3 | 7.8 | 40.2 |

*Variability problem; summary of results.* 1. Variability in the amplitude of inspiration is but slightly different from the variability of expiration in both stutterers and normals during speech.

2. Stutterers differ but slightly from normals in variability in the amplitude of inspiration and expiration during speech.

3. Table I shows that there is a marked difference between the variability of the time of inspiration and the variability of the time of expiration in stutterers during speech.

(a) The ratio of the A.M. of the time of inspiration to the A.M. of the time of expiration is .227 .

(b) The ratio of the C.V. of the time of inspiration to the C.V. of the time of expiration is .81 .

(c) The A.M. of the expiration-time shows an increase of 340 per cent over the A.M. of the inspiration-time.

(d) The A.M. of the C.V.'s of expiration-time shows an increase of 23 per cent over the A.M. of the C.V.'s of the time of inspiration.

4. Table II shows that there is a marked difference between the variability of the time of inspiration and the variability of the time of expiration.

(a) The ratio of the A.M. of the time of inspiration to the A.M. of the time of expiration is .194 .

(b) The ratio of the C.V. of the time of inspiration to the C.V. of the time of expiration is .8 .

(c) The A.M. of the expiration-time shows an increase of 414 per cent over the A.M. of the inspiration-time.

(d) The A.M. of the C.V.'s expiration-time shows an increase of 25 per cent over the C.V.'s of the time of inspiration.

5. Stutterers are 29 per cent more variable than normals in the time of inspiration and are 27 per cent more variable than normals in the time of expiration.

6. If the severe stutterers are grouped together and the mild stutterers are grouped together and both are compared to the normals we find:

(a) The severe stutterers are 52 per cent more variable in the time of inspiration.

(b) The severe stutterers are 40 per cent more variable in the time of expiration.

(c) The mild stutterers are 2.8 per cent more variable in the time of inspiration.

(d) The mild stutterers are 5 per cent more variable in the time of expiration.

7. Mild stutterers show approximately the same increase of variability in the time of inspiration and expiration over normals that the whole stuttering group showed in the variability in the amplitude of inspiration and expiration over normals. The greater variability appears in the variability of the amplitude and time of expiration.

8. If the normals above the group average are grouped together the severe stutterers are still 29 per cent more variable in the time of inspiration, and 28 per cent more variable in the time of expiration.

9. This comparison shows important differences between the severe stutterers and the mild stutterers.

10. Severe stutterers show tremendous increase in variability over normals in the time of inspiration and expiration.

11. There are but slight differences between stutterers and normals in the C.V.'s of inspiration and expiration-time during rest breathing.

12. For normals the ratio of the A.M. of the C.V.'s for the inspiration-time in rest breathing to the A.M. of the C.V.'s for

the inspiration-time during speech is .34 . The corresponding ratio for expiration-time is .30 . For stutterers the corresponding ratios are .31 for inspiration-time and .24 for expiration-time.

13. The C.V.'s of both inspiration and expiration-time during speech is approximately three times as great as the corresponding ones for rest breathing.

14. The ratio of the A.M. of the inspiration-time and the A.M. of the expiration-time for stutterers in rest breathing is .52 . During speech it is .22 . It frequently happens that there is a considerable period of rest at the end of active expiration before the following inspiration begins, which is counted as part of the expiration-time. This accounts for a large part of the difference.

15. The ratio of the A.M. of the inspiration-time and the A.M. of the expiration-time for normals in rest breathing is .55 . During speech it is .21 .

16. Speech decreases the inspiration-time and extends the expiration-time. The amount of change is approximately equal for both normals and stutterers.

(a) In stutterers speech reduces the inspiration-time 40 per cent and extends the expiration-time 42 per cent.

(b) In normals speech reduces the inspiration-time 46 per cent and extends the expiration-time 37 per cent.

17. The grand average for the full breath intervals is approximately the same for stutterers and normals in rest breathing.

The grand average for the full breath interval is greater during speech than during rest breathing in both stutterers and normals.

(a) For stutterers the gain in length is 14.6 per cent.

(b) For normals the gain in length is 7.3 per cent.

*Descriptive problem; description of typical curve forms.* In the interest of a more adequate analytical description of the breathing curves of both normals and stutterers than has yet been made, a number of typical recurrent patterns have been selected as a basis for the description. These typical curves are divided into three groups: one describes the course of inspiration and the beginning of expiration, another shows the general course of expiration, and a third illustrates the end of expiration and

the onset of inspiration. These selected patterns represent generalized rather than particular curves. Individual curves will conform generally to these types although in each case some irregularity and departure from the generalized forms may be apparent. The relative frequency with which the different forms appear will be clear from the tables. Thus there are some typical forms which are common to many individuals, while others are manifested in few individuals. It is apparent also that these forms are quite independent of any relation to specific articulatory processes.

In addition to the generalized forms, many irregular forms are shown in the plates illustrating the great variety of anomalies as well as certain general tendencies in the same individual and in different individuals. Apparently nowhere is there any relation between the pattern form and the attempt to produce any particular sound or group of sounds. Since the typical patterns are common to both stutterers and normals, the percentages are exclusive of the numerous anomalies that occur in stutterers.

In order that the typical forms may be understood more easily, a brief description of each form is given.

*Beginning.* 1. Inspiration comes promptly to an end and speech begins without delay, no breath being lost at the beginning of speech.

2. There is a short expiration of air before speech begins, after which speech proceeds as in 1.

3. Inspiration does not come promptly to an end but is slowly drawn out over a considerable period of time and is maintained almost at a level before speech begins. Inspiration passes gradually instead of sharply into expiration.

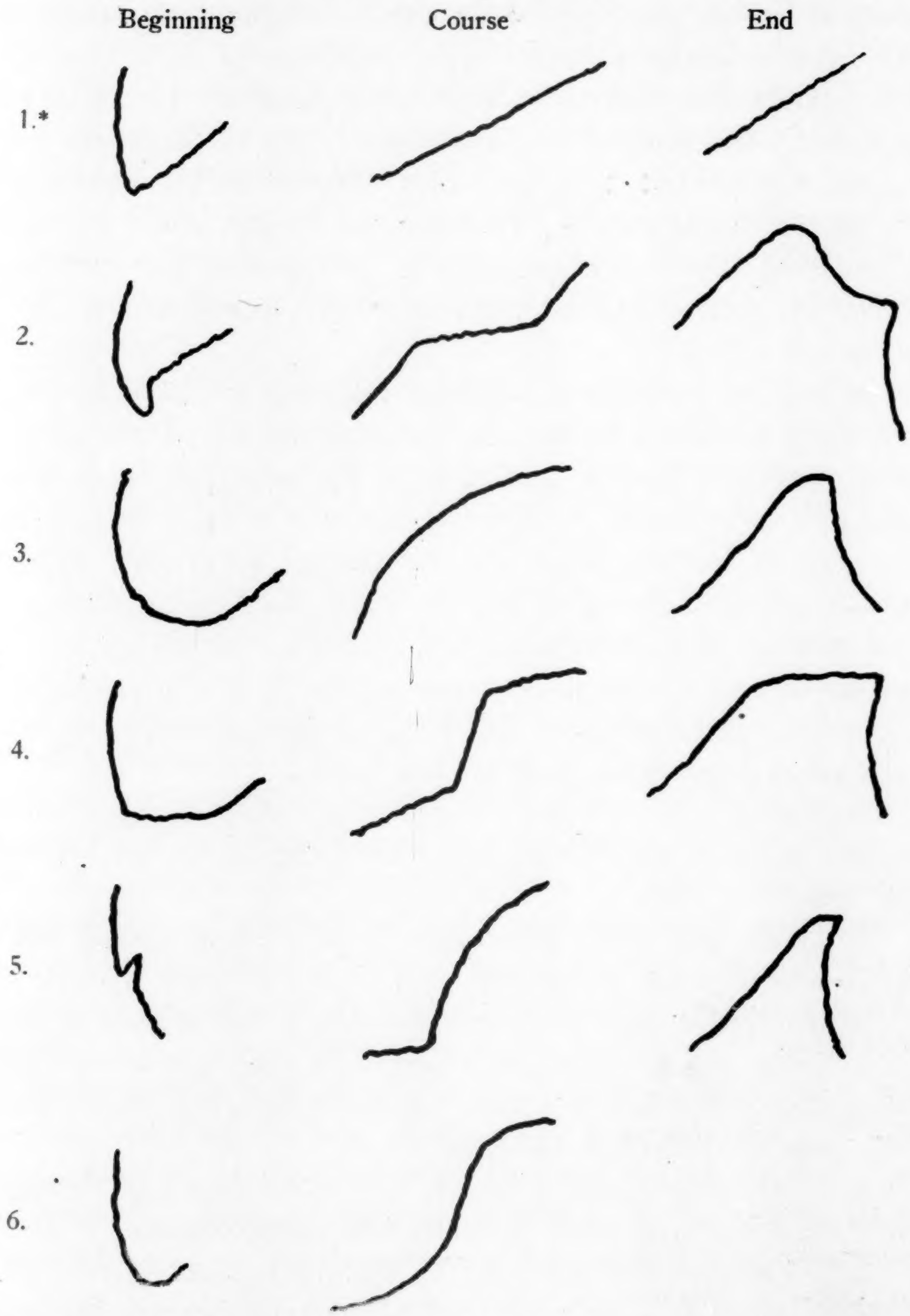
4. Inspiration comes promptly to an end but the "breath is held" for a considerable period before speech begins.

5. Inspiration is interrupted by a short expiration.

6. Inspiration is slow and prolonged before expiration begins but not nearly so long as in 3. There is the same gradual transition from inspiration to expiration as in 3.

*Course.* 1. Expiration follows a regular uninterrupted course throughout the interval.

### Typical Curve Forms




* Numbers here correspond to those in the tables.

2. The course of expiration begins with a rapid rise until speech begins. It then proceeds evenly for a time until another rapid rise brings the course to an end.

3. Expenditure of air is rapid at the beginning of the interval but gradually slows down to the end where speech is continued on a decreasing quantity of air.

4. The regular course of expiration is interrupted in the midst by a very sudden expulsion of breath.

5. A short period of speech is terminated by the sudden expiration of the remaining supply of air.

6. The course of expiration shows a period of acceleration in the middle, before and after which the course is regular.

*End.* 1. Expiration is continued vigorously and regularly to the end of the interval where inspiration follows without delay.

2. Expiration terminates gradually and passes into a slow preliminary inspiration before the general sweep of inspiration begins.

3. Expiration ends and inspiration begins so gradually that the one passes into the other without a definite time of demarcation.

4. Expiration is carried to its highest level where the " breath is held " for a long interval of time before inspiration begins.

5. The course is similar to 4, the difference being that the " breath is held " for a much longer time in 4.

*Interruptions.* In the course of an expiration it frequently happens that there are short inspiratory interruptions of much greater magnitude than the expected fluctuations of ordinary speech. A single expiratory interval may have one or more of such interruptions. They may occur at any time in the course of the expiration and may be more or less extensive in amplitude. The lower-chest curve in Plate I, Fig. 1, exemplifies an interval with four such interruptions. Similarly, the lower-chest curve in Fig. 5 shows an interval with one interruption. A comparison of the frequency of occurrence of interruptions up to five per interval in both stutterers and normals shows a much larger percentage of such interruptions for stutterers.

*Descriptive problem; summary of observations on typical curves.* 1. The rank order of highest frequency for beginnings was 1, 6, 2, for both normals and stutterers. The other three types were comparatively infrequent in both normals and stut-

terers. Normals showed greater frequency on 1 and less on 6, with about an equal distribution on 2.

2. The rank order of highest frequency for ends was 1, 3, 5, for both normals and stutterers. Normals showed greater frequency on 1 and 4, less frequency on 3, and equal frequency on 2.

3. The rank order of highest frequency for courses was 1, 5, 4, 2, for both normals and stutterers. Normals show a greater frequency on 5, 4, and 2, but less on 1. The stutterers show higher frequency on 3 and 5. The difference in frequency between normals and stutterers must be interpreted in the light of the fact that the percentages were calculated for the generally typical forms only. Hence the figures for stutterers are much higher on the regular forms than if all forms were counted. In some cases of severe stuttering the anomalous curves comprise from 25 per cent to 50 per cent of all the curves, in a few cases of mild stutterers from 10 per cent to 25 per cent, and in a few cases of normals up to 10 per cent.

4. The stutterers show approximately twice as many expirations that were interrupted by inspirations as normals show and the frequency of such interruptations within the expirations was greater.

*Descriptive problem—general description of plates.* In all records a downward stroke of the stylus indicates an elevation of the larynx or an inspiration; an upward stroke of the stylus indicates a depression of the larynx or an expiration. In all of the plates the figures are considered as being numbered from left to right. Where two rows of figures are shown the second row follows the first and the numbers of the figures continue in sequence. In all plates where four curves are shown, the curves appear in the following order, reading from top to bottom: laryngographic, upper-chest, lower-chest, and abdominal breathing. In some figures the signal line and the time line registering time in seconds appear below. In all figures the natural size is reduced approximately three and one-half times.

The curves in Plate I are normal curves. The general synchronism of the curves is apparent. The lower-chest curve shows the greatest sensitivity found in the breathing curves. In Fig. 3

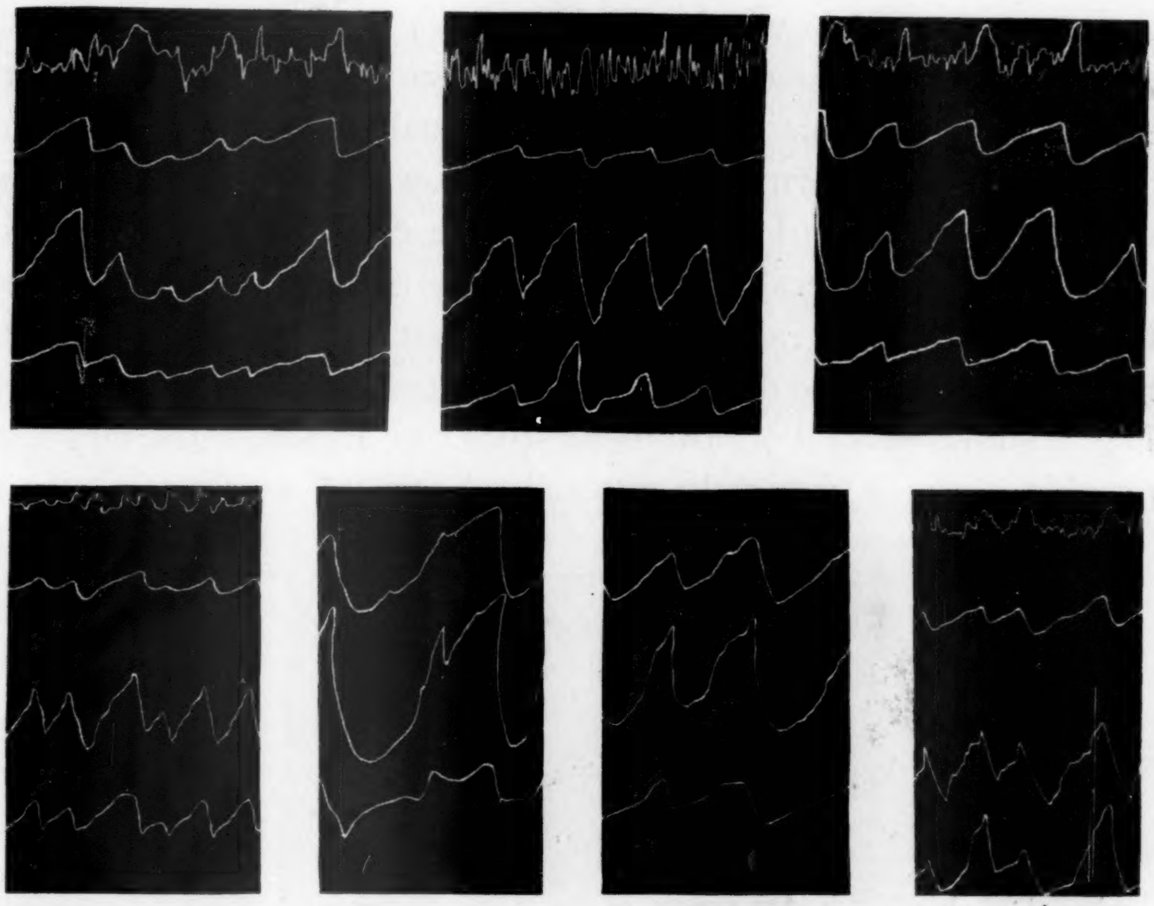


PLATE I. All figures except 5 and 6 show the curves in the regular order. In Figs. 5 and 6 the laryngographic curve is omitted, all other curves being in the regular order.

the laryngographic curve[4] shows that in some cases inspiration is accompanied by a downward movement of the larynx while other cases do not show this relation. Both the relative and absolute amplitudes of the breathing curves vary from person to person.

In Plate II, Figs. 1 and 2 show typical spasms in the breathing mechanism of the stutterers. This is especially clear in the lower-chest curve. The fine rapid oscillations in the laryngographic record indicate clonic movements. These two figures show considerable similarity in pattern although the words on which trouble occurred were quite different. Fig. 3 shows two occasions where stuttering took place upon the same word. The stuttering appears to be of about equal severity on both occasions. The curve patterns, however, are seen to be quite different. Fig. 4

[4] No attempt is made in this study to analyze the movements recorded by the laryngograph into their component elements. They are simply described as laryngeal movements.

shows an interval in which three instances of stuttering occurred, yet the general course of the curves would not indicate serious disturbances. In this case it is the unusual length of the interval that indicates abnormality. Fig. 5 shows a breathing interval with three periods of interruption. The course of inspiration is interrupted by several short inspirations which tend to prolong the interval. The rapid oscillations seen in the laryngographic record suggest grave disturbances in the movements of the larynx. Fig. 6 shows several occasions of stuttering in which the laryngographic curve is distinctly unusual. Some of the stuttering in-

Plate II. All curves follow the regular order. The signal line where occasions of stuttering are recorded together with the words upon which difficulty occurred appears in all figures.

tervals are ended by a sharp downward movement of the larynx which was accompanied by a sound closely resembling a bark. This record shows that difficulty occurred twice on the same word. In the one case it was severe. It occurred near the middle of the interval and culminated with the sudden downward thrust of the larynx. In the other case it was mild and occurred at the end of the interval with no serious disturbance indicated. On the other hand, it will be seen that the disturbances which occurred on "justice" and "peace" very closely resemble the disturbances on "tin shop." Thus we have occasional similar patterns with different words and different patterns with the same words. The inconsistency is apparent.

Plate III, Fig. 1, shows great irregularity in the course of the breathing curves although stuttering is neither severe nor fre-

quent. Fig. 2 shows two occasions of severe stuttering, in the first of which the course of expiration is interrupted. An attempt is made to speak during part of the inspiration in both cases. Clonic spasms are present in the lower-chest curve, and in the laryngographic curve. Fig. 3 shows an occasion of stuttering of considerable duration, yet none of the curves indicate severe disturbances. There are such occasions of stuttering where syllables or sounds are repeated so that so far as the breathing or the laryngeal movements are concerned no difficulty is suggested.

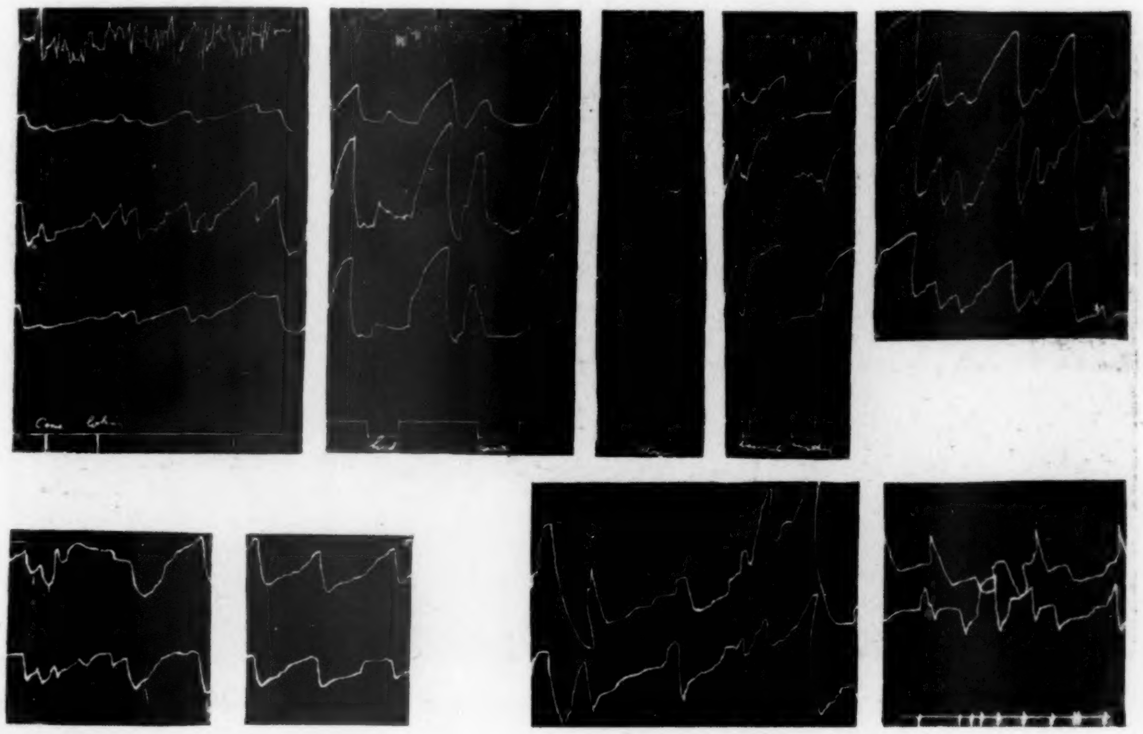


PLATE III. In Figs. 1, 2, 3, and 4, all curves are in the regular order. In Fig. 5 the three breathing curves appear in the regular order. In Figs. 6, 7, 8, and 9, the lower chest curve appears at the top and the abdominal curve below it. Occasions of stuttering are indicated on the signal line.

The emission of the sounds is regular although the sounds may not be meaningful language symbols. The cases of difficulty shown in Fig. 4 differ in severity and duration and the patterns throughout are entirely different. It may be seen here as in Fig. 2 that fluctuations which occur in the lower-chest curve may not be detected in either of the other breathing curves. Fig. 5 shows another example of the greater sensitiveness of the lower-chest curve. The course of expiration is interrupted by short inspirations. Fig. 6 shows the breaking up of a breathing interval almost

beyond recognition although stuttering is not severe. Fig. 7 shows the normal relations of breathing relatively undisturbed although stuttering is as severe as in the case shown in Fig. 6. Fig. 8 shows a very long interval which is considerably broken up. The deep inspiration at the beginning and the very deep inspiration which introduces the next interval contrast with the short inspiratory interruptions. Fig. 9 shows what at first sight appears to be direct opposition of the breathing curves during frequent short occasions of stuttering. But close comparison will show

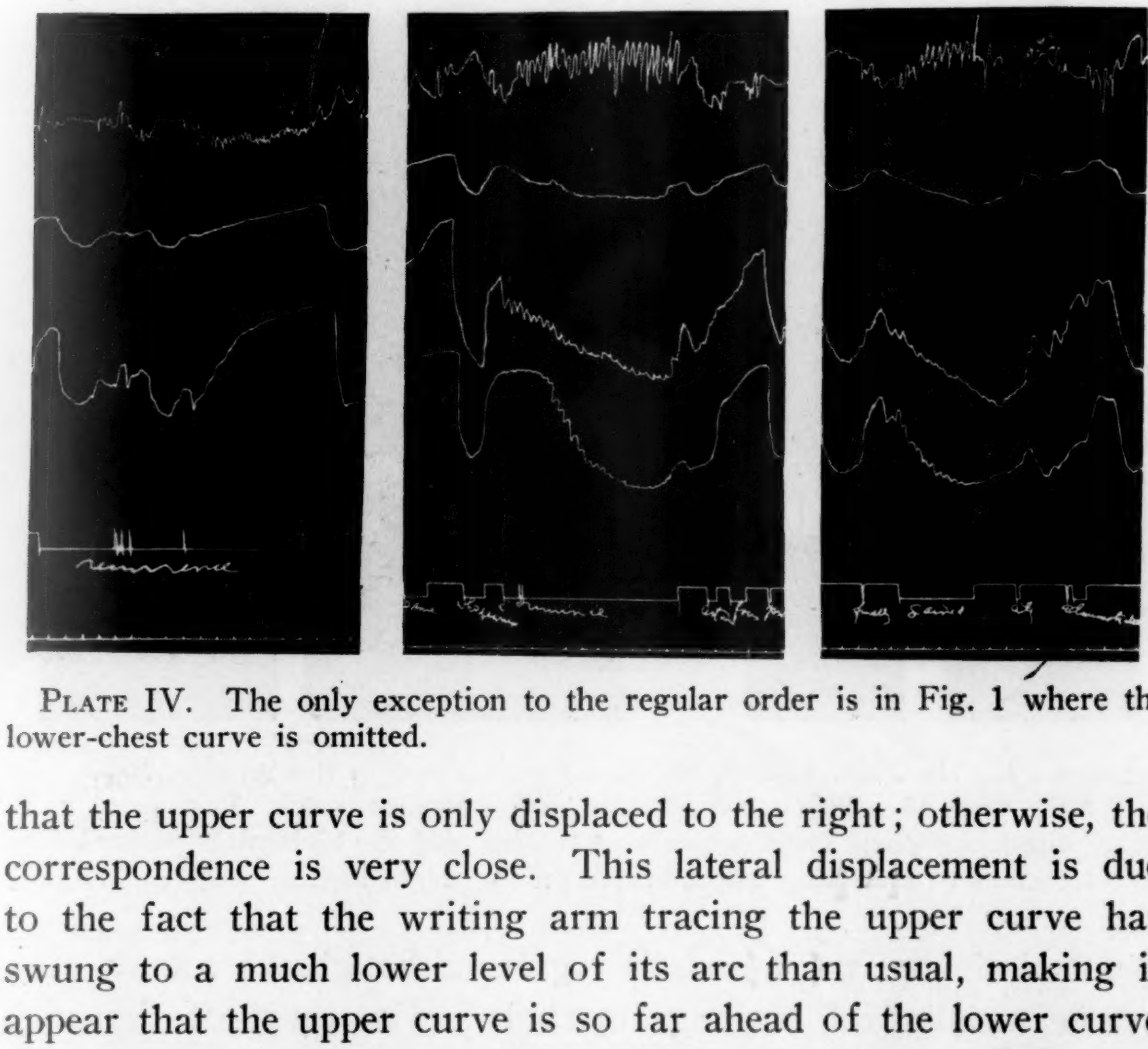


PLATE IV. The only exception to the regular order is in Fig. 1 where the lower-chest curve is omitted.

that the upper curve is only displaced to the right; otherwise, the correspondence is very close. This lateral displacement is due to the fact that the writing arm tracing the upper curve has swung to a much lower level of its arc than usual, making it appear that the upper curve is so far ahead of the lower curve that they seem to be in opposition. This makes it clear that where simultaneous curves are made of operations which are variable relative to each other, by means of lever recording arms, temporal synchronisms may be evaluated only when the curvature of the arc of the writing arm is taken into account in the same way in which it had to be accounted for in the measurement of lateral movement.

Plates IV, V, and VI are all from the same *O* and are presented to show the great variety that may occur in the same individual. Plate IV, Fig. 1, shows an extended attempt to utter a single word. It will be noted that in the laryngographic record there are two short tonic spasms which give way to a long clonic spasm which ends with a severe sudden downward thrust of the larynx. In the first part of the interval both upper-chest and abdominal curves show a complete breaking up of the normal course of expiration. The latter part of the interval shows the resumption of the normal course. Fig. 2 shows severe stuttering during which appear clonic movements of the larynx of

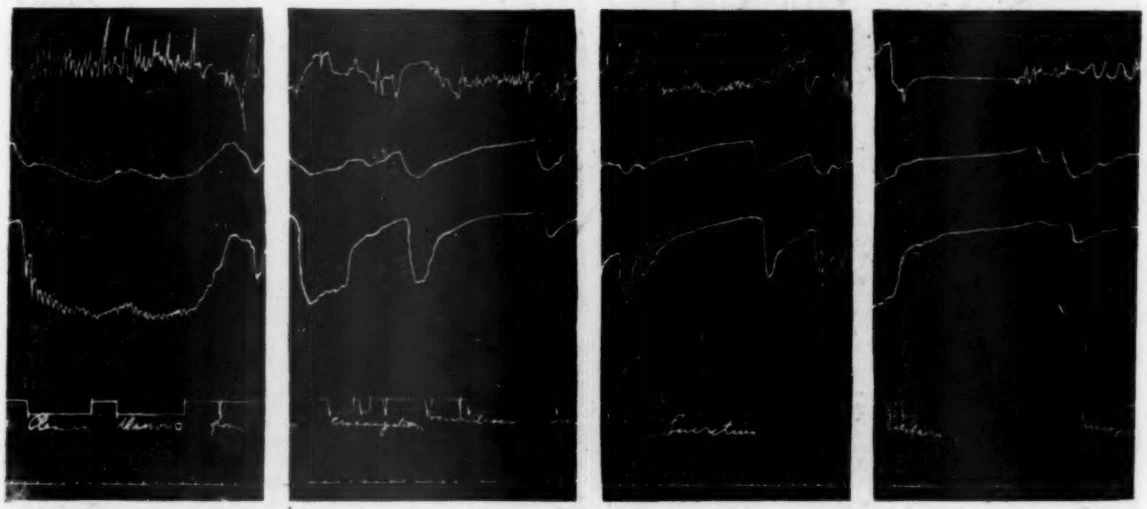


PLATE V. The lower-chest curve is omitted in all figures, the other curves being in the regular order.

slightly less frequency but much greater amplitude than appear in Fig. 1. The clonic spasm is shown in all the breathing curves. Fig. 3 shows a similar pattern in all curves but the words uttered are entirely different. These clonic patterns are characteristic of this subject only. Comparison with Plate II, Fig. 6, shows that these jerks in the larynx may occur in severe stuttering where no spasms occur in the breathing.

A feature of frequent occurrence is seen in the abdominal curves where a deep inspiration slowly passes into a rapid expiration producing a U-shaped dip in the curve. This type of curve may be observed in other records also. In Plate V, Fig. 1, spasms similar to those in Plate VIII are seen to continue throughout a long interval. Again, the patterns are associated with entirely

different words. In the first part of Fig. 2, only the abdominal curve shows a clonic spasm; in the last part of Fig. 2 the clonic spasm occurs again in the laryngographic curve. It will be seen that spasms may occur independently in one curve without appearing in another although they more frequently appear in the different curves together. Fig. 3 shows an extended period of difficulty in which shifts are made in all curves. Fig. 4 shows a severe period in which all curves show a tonic spasm. Plate VI, Fig. 1, shows a series of sudden upward thrusts of the larynx.

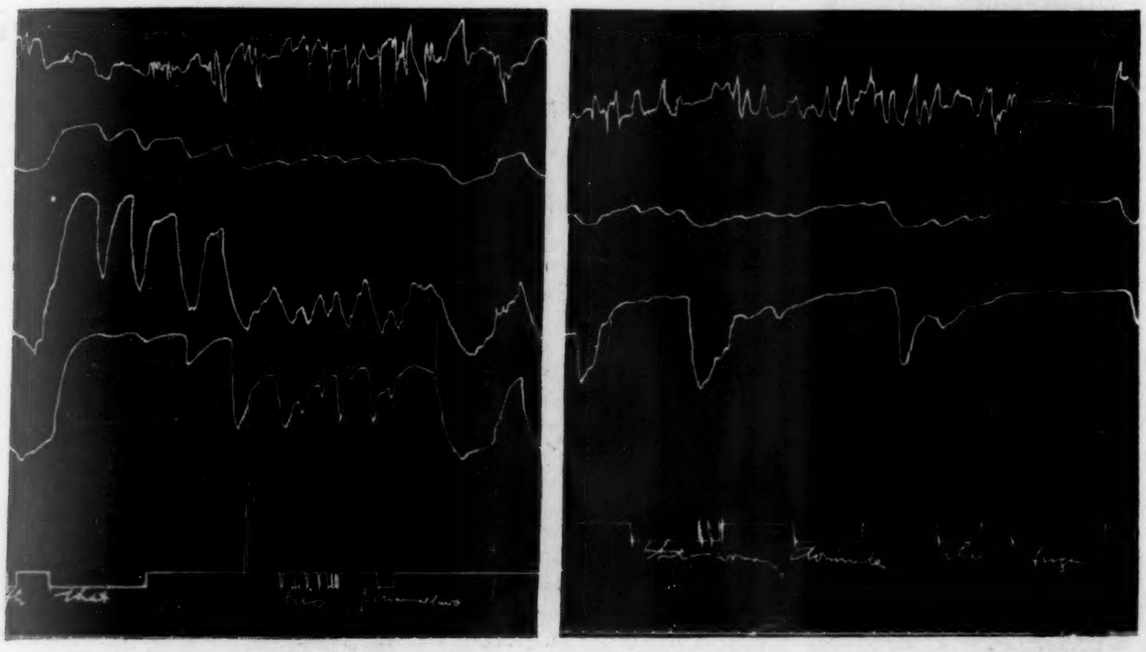


PLATE VI. The regular order is followed except in Fig. 2, where the lower-chest curve is omitted.

The lower-chest curve shows four rapid expirations and inspirations following a long forced expiration. During these movements of the lower-chest curve, the abdominal curve shows very slight disturbance. Both curves then come suddenly into synchronism where frequent short inspirations and expirations follow. Fig. 2 shows prolonged, forced expirations. The tonic spasm on the word "finger" does not appear elsewhere although the other difficulties are as severe and of as long duration.

Other individual stutterers exhibit curves which in many respects are peculiar to the individual. This same variety which has just been pointed out may be found in other cases. Many of the patterns are recurrent, as we have seen, but they are not

consistent. Many varieties are possible. They show no relation to the particular sound or group of sounds on which the difficulty occurred.

*Summary of the description of plates.* The general asynchronism of all the breathing curves may be interrupted during a paroxysm of stuttering in one or more of the curves independently of the others. Stuttering may or may not be accompanied by tonic or clonic spasms but spasms have not been found except during stuttering. Occasionally the temporal relations of the breathing curves may be so disturbed during stuttering that they seem to be in opposition to each other. Breathing intervals may be either greatly prolonged or shortened during stuttering but in many cases no such disturbance is apparent. Stutterers show a much higher frequency of interrupted intervals than normals. Attempts to speak during inspiration were found only in stutterers. A paroxysm of stuttering may extend over two or more breathing intervals. Severe stuttering may occur without being accompanied by any apparent disturbance in the curves. There is no apparent relation between curve patterns and the attempt to produce any particular sound or group of sounds.

*General summary.* The study of patterns showed that there are some observable, typical, recurrent patterns which are not, however, definitely associated with the attempt to produce any particular sound or group of sounds. They are in this sense general and not specific patterns. A few patterns have been found characteristic of several individuals while a few have been found characteristic of only one individual.

The study of variability showed that there is no significant difference between stutterers and normals with reference to amplitude of inspiration and expiration. Stutterers were found to be 52 per cent more variable than normals in the time of inspiration and 46 per cent more variable than normals in the time of expiration. Speech breathing is approximately three times more variable than rest breathing for both stutterers and normals. The average length of the full-breath interval during speech is greater than for rest breathing in both stutterers and normals,

the gain being 14.6 per cent for stutterers and 7.3 per cent for normals.

The descriptive study of curve forms showed that stutterers present from two to five times more anomalous curves than normals, although in the remaining curves the rank order of frequency is comparable to that of normals. Stutterers showed approximately twice as many expirations that were interrupted by inspirations as normals and the frequency of such interruptions within the expiration was greater. Stuttering may or may not be accompanied by tonic and clonic spasms in the breathing and the laryngeal apparatus, by temporal opposition of the breathing curves, by attempts to speak on inspiration, by greatly prolonged expiration, and by a breaking up of the normal rhythm of speech.

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# MEASUREMENT OF MUSICAL TALENT FOR THE PREDICTION OF SUCCESS IN INSTRUMENTAL MUSIC [1]

BY

WILLIAM SEVERT LARSON

I. *Introduction: problem, historical approach, the objective nature of the criterion.*

II. *Presentation of data: theoretical basis of interpretation, distribution of scores, data in terms of central tendency.*

III. *Interpretation: beginning instrumental classes, the high school advanced orchestra, comparison of all groups, the effect of training, summary and conclusions.*

IV. *The problem of prediction.*

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## I. INTRODUCTION

*Problem.* The purpose of this study is to determine whether those musical capacities, which may be tested by the Seashore "Measures of Musical Talent," have been indirect criteria in the selection of members of instrumental musical organizations at different levels of achievement,[2] and on the basis of results obtained, to determine whether the Seashore tests may be of value in the prediction of success in instrumental music. The problem has been studied particularly in the interest of avocational guidance in instrumental music in the public schools. The usual method of determining whether an individual can succeed in music is to give him a trial. Teachers of music are well acquainted with the fact that there are all degrees of success and failure with this procedure. The maladjusted music

[1] It has been the pleasure and good fortune of the writer to have had the counsel of Dean Carl E. Seashore, who, through a wide experience due to his unremitting effort in the development of aptitude tests in music, has been able to give most helpful instruction and guidance in the preparation for and direction of this study in the psychology of music.

[2] This statement refers to the possibility that the innate musical aptitudes, which are subject to quantitative treatment in the Seashore tests of musical talent, are potent ones, in that, on the basis of these, members of musical organizations have been selected through a sifting process, their musical growth depending relatively on the possession of these innate talents.

pupil, the failure to discover many talented pupils, and the time and expense elements involved are problems which accrue to this traditional device.

The possession of talent is basic for success in music. Contributions to the understanding of the meaning of musical talent have come largely through the efforts of psychologists in various research laboratories. Investigators have found that musical talent is not a single talent. According to *Seashore* (14) musical talent is a "hierarchy of talents, many of which are entirely independent of one another . . . bestowed very unequally upon individuals." Quantitative measurements have shown that an individual may possess these elemental capacities in varying degrees. He may be low in all, or high in all; he may be low in some, average in others, and high in others; or he may possess an average degree of all the talents.

*Seashore* (14) has pointed out that each individual has a definite physiological limit beyond which he can no longer detect differences in basic sensory musical capacities. Training and practice have little if any effect on these elemental capacities. Also there is no direct relation between age and these capacities. Such factors as attention, information, sustained effort, and application operate in favor of adults; but these advantages may be balanced by a different set of norms for age-groups below the adult. There is also no significant correlation between general intelligence and innate musical capacities. Such, in brief, are the tenets upon which the psychology of music is based.

*Historical.* The large amount of laboratory investigation establishing these principles of the psychology of music suggests the need of further research in the practical field. These principles should have a wide application. But there has been a scarcity of applied studies. The general literature in the psychology of music shows such investigations as a survey of musical talent (12) primarily for the establishment of norms; studies on the racial differences in musical capacities such as that made by *Johnson* (6); and studies of the musical capacities of students in music schools such as those by *Gaw* (5) and *Brennan* (1).

These studies have been of importance in substantiating the experimental work of the laboratories and showing the need for the application of the principles of the psychology of music in the guidance of musical talent.

The most important contribution to a guidance program is the pioneer work of *Stanton* at the Eastman School of Music. This investigation (20) was concerned with an intensive study of all music students in that school over a period of four years.[3] The most significant part of the study deals with a comparison of the scores in capacity-tests with the fluctuation of the total enrollment in the school. There is also the comparison of teachers' estimates of talent with fluctuation of enrollment and scores in capacity-tests. The results show that of 242 cases, 47 per cent of those testing "low average" and "below" (below average) remained in the school for a year. Over one-half of the low talent had voluntarily discontinued their studies. On the other hand 84 per cent of the talent above average (A or B) remained one year. In another group of 149 D or E students and 149 A or B students, it was found that after three years' time 86.7 percent of the D or E students were not enrolled in the school. Only 13 per cent continued. At the end of this three year period,

[3] Just before the publication of this study, Dr. Stanton has presented the results of four additional years of research at the Eastman school in a new monograph, "Prognosis of Musical Achievement." The new contributions include the development of a five-fold classification of safe, probable, possible, doubtful, and discouraged. Assignment to one of these divisions depends upon the scores made in (1) capacity tests (Seashore Measures of Musical Talent) and (2) a comprehension test (The Iowa Comprehension Test). The relationship of the student's classification to accomplishment is shown by (1) the annual academic survivors in each of the five groups, (2) the September 1928 status of 164 classified entrants beginning their fourth year, (3) the scholarships and honors awarded in each group, and (4) students in each group participating in the recitals of the school. The results in achievement in each of these four aspects are very markedly in favor of the students classified in the higher groups. The practical significance of these findings may be shown by quoting Dr. Howard Hanson, director of the Eastman School of Music, who, believing strongly in the efficacy of the experimental work in the school, says, ". . . I shall recommend to the Board of Directors the further limiting of students entering the Eastman School by eliminating applicants in Group Four, in the same way that Group Five applicants were excluded by me in the entering class of 1928 after a study of the achievements of that type of student over the previous seven years." (From the "Foreword" of the study.)

36 per cent of the A or B students were not enrolled in the school, while 63.7 per cent were continuing music study.

As a result of this study, *Stanton* remarks (p. 27), "If those who test the highest continue their music study the longest and those who test the lowest continue their music study the shortest time, why admit to the school those who test the lowest?" She concludes (p. 42), "Influenced by the information presented in this report, the faculty of the Eastman school decided to admit only those applicants whose musical talent warrants some continuity of musical training."

*Approach.* If in one of the most prominent conservatories there is a large turnover of music students, which demands remedial measures, it is reasonable to assume that an analogous condition is true in public school systems. In fact, since a conservatory is supposed to have the more talented students, it seems that there would be a greater need for a guidance program in the public schools where there is apt to be less chance for selection, particularly in the beginning instrumental classes. The public schools, with their rapidly increasing enrollment in the instrumental classes, therefore furnishes a field that seems to warrant investigation. Most supervisors or instructors of instrumental music will testify to the fact that there is a considerable turnover in the instrumental classes. And it is common knowledge that music instruction is expensive due to the fact that it takes a considerable amount of time to become a proficient player, and that music lessons and instruments are costly. In the light of these facts it was decided to investigate the relationship between the musical capacities measured by the Seashore tests and achievement in instrumental music, hoping to obtain results that would be of significance in forming a plan for guidance in the teaching of instrumental music.

A school system[4] which has had a well-organized instrumental department for a number of years under the same supervision was selected for the study. Representative groups, having well-defined levels of achievement, were chosen for experimentation.

[4] Lincoln, Nebraska, Charles B. Righter, Jr., supervisor of instrumental music.

The groups ranged in ability from beginning classes, which had just been organized, to the high school advanced orchestra.[5]

With the exception of four beginning instrumental classes, these groups were taken from the high school and one of the junior high schools. The high school classes have been conducted for a number of years by the supervisor of instrumental music and the junior high school classes have been under his supervision in a well-organized program. Since distinct differences in ability were to serve as criteria, the choice of schools with well-established instrumental programs seemed as important as the selection of the classes with well-defined levels of achievement. The other large junior high school, which had just been opened, might have been affected by the newness of the organization and might not have furnished such well-defined limits of achievement. The only classes that were tested for this study in this new junior high school were the four beginning instrumental classes,[6] to which these objections as to organization would not apply.

The first division included eight beginning instrumental classes from the two junior high schools. This group was composed of the beginning violin class and the beginning wind instrument class of each school each semester.

In the next division were the classes that followed the beginning classes in the junior high school. There were three organizations in this division, the junior high school preparatory orchestra, the band, and the junior high school advanced or-

[5] This wide variation in ability may be shown by reference to the compositions listed on one of the typical public programs of the high school advanced orchestra. This program includes the "Barber of Seville" overture by Rossini, the *Andante con moto* of the Schubert "Symphony in B minor," the Jarnefeldt "Prelude," and Gounod's "Ballet Music" from Faust. The orchestra from this school won second place in the mid-western contest held before the Music Supervisors National Conference in Kansas City in 1925. It also won first place in the Nebraska State Music Contest in as many attempts of competition. Just before this study was submitted for publication, this orchestra was awarded first place in the first National High School Orchestra Contest, Iowa City, May, 1929.

[6] These beginning classes were included with the beginning classes of the other junior high school, for it seemed desirable to have as large a group as possible, so long as it was homogeneous, in order to reduce errors in sampling.

chestra. The best players in all sections—string, brass, wood-wind, and percussion—were selected by the instructors for the junior high school advanced orchestra. The next best players, with the exception of the strings, were placed in the band, and the poorer players from all sections made up the junior high school preparatory orchestra. The junior high school advanced orchestra and the junior high school preparatory orchestra were selected for the experiment, because these two groups represented distinct levels of achievement and included players from all sections.

The high school instrumental department was organized in practically the same way. There were two preparatory orchestras, band, and advanced orchestra. The differences were that there were no beginning instrumental classes, there were two preparatory orchestras, and students were permitted to play in both the band and the advanced orchestra. Since there were many students who did not need the training in the high school preparatory orchestra but were qualified to be admitted directly to the high school advanced orchestra, it was decided that the high school advanced orchestra should serve as the next distinct group at a higher level of achievement.

*The objective nature of the criterion.* The four groups selected as representing four distinct stages of ability were the beginning instrumental classes of 125 students, the junior high school preparatory orchestra of 30 members, the junior high school advanced orchestra of 31 members, and the high school advanced orchestra of 50 members. The selection of these four groups at distinct levels of achievement for the purpose of showing the relationship between capacity-tests and achievement seemed to be of advantage in that it gave a more objective criterion and was not so amenable to the dangers of the "personal equation" in teachers' estimates of achievement.

The tests used in this experiment were the Seashore "Measures of Musical Talent,"[7]—the sense of pitch, the sense of intensity, the sense of time, the sense of consonance, the sense of rhythm, and tonal memory. The tests were given in accordance with the

[7] Recorded on Columbia phonograph records 53000D–53005D.

manual of instructions (**12**). The testing was done during the time of the regular lessons or rehearsals in the second week of the first semester and in the fourth week of the second semester.

Results of the tests are given in the percentile norms[8] as shown in the Seashore manual (**12**). The school system was on the 6–3–3 plan. Eighth grade norms were used for students in the junior high school and adult norms were used for the high school students.

## II. Presentation of Data

In order to show the relationship which exists between musical capacities as measured by the Seashore tests, and achievement in music, the data gathered from the testing program described in the foregoing section are presented (1) in the form of general group distributions and (2) in terms of measures of central tendencies.

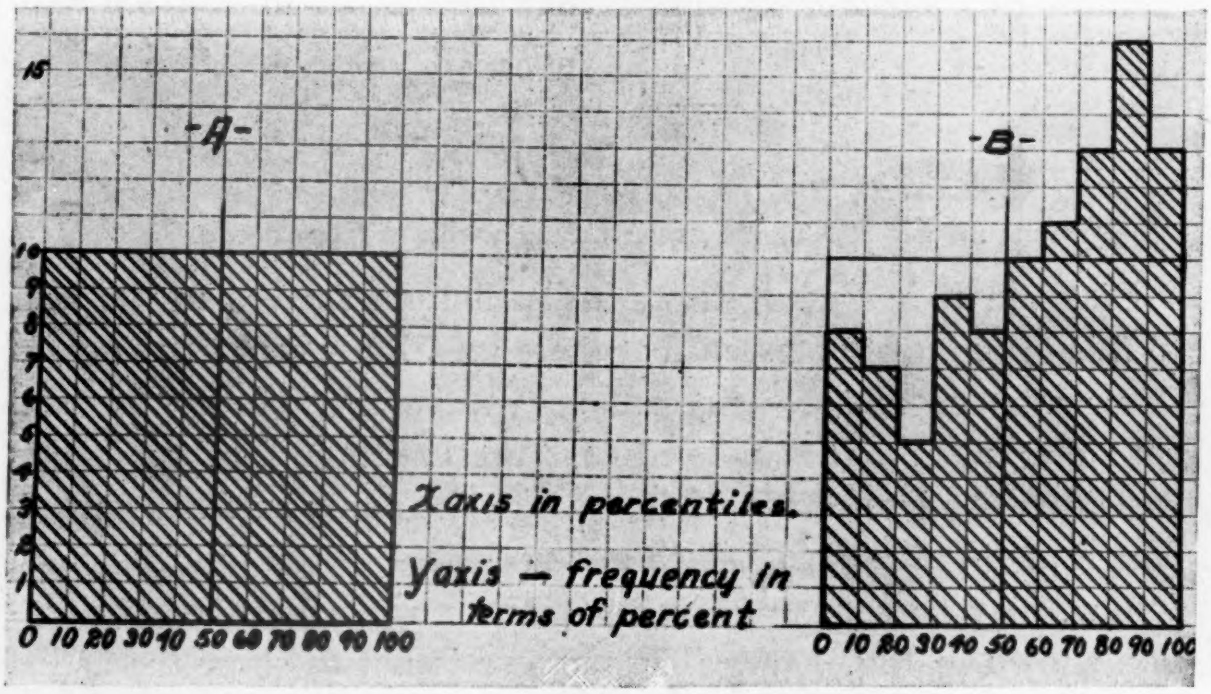



Fig. 1

*Theoretical basis of interpretation.* Diagram A in Fig. 1 represents an hypothetical distribution in which the total population has been tested in a certain capacity. This avoids all errors due to sampling or selection. As the norms for the tests are in

[8] Scores are given in this study in terms of these percentile norms unless otherwise specified.

percentiles, it is convenient to use a diagram (see A of Fig. 1, which is based on A of Table I) with each of the 10 equal divisions along the base line representing the deciles. Each of the 10 divisions in the column of each decile allows one per cent of the total for each division. Therefore each of the 100 squares in the diagram represents 1 per cent of the general population. A representative 45 per cent talent would be found in the fifth square of the fourth column.

TABLE I. *Showing group distributions (theoretical)*

| | A | | B | |
|---|---|---|---|---|
| Percentile Scores | F* | %† | F | % |
| 90–100 | 10 | 10.0 | 26 | 13.0 |
| 80– 89 | 10 | 10.0 | 32 | 16.0 |
| 70– 79 | 10 | 10.0 | 26 | 13.0 |
| 60– 69 | 10 | 10.0 | 22 | 11.0 |
| 50– 59 | 10 | 10.0 | 20 | 10.0 |
| 40– 49 | 10 | 10.0 | 16 | 8.0 |
| 30– 39 | 10 | 10.0 | 18 | 9.0 |
| 20– 29 | 10 | 10.0 | 10 | 5.0 |
| 10– 19 | 10 | 10.0 | 14 | 7.0 |
| 0– 9 | 10 | 10.0 | 16 | 8.0 |
| | 100 | | 200 | |

* F means frequencies.
† % means the per cent of the group falling within a given decile.

Diagram B in Fig. 1 shows a distribution skewed to the left. In this group it can be seen that there are 37 per cent of the cases below average and 63 per cent above average. In comparison with diagram A, it is noticed that the lower half of the range has suffered a loss of 13 per cent which the upper half has gained. Diagrams of this type, which are presented in the figures which follow, may be compared in like manner with the normal situation shown in Fig. 1, A. The purpose is not to show the actual average of the groups but to portray the relative position of the talent of a group in comparison with that of the normal situation as it is shown in this first diagram. However, the general distribution may be an indication of the average. Comparisons will be in terms of this theoretical distribution of percentiles. The reliability of this procedure is limited somewhat by such factors as errors in sampling, errors in testing, validity of the tests, and errors in the norms of the tests, *etc.*

It can be seen that any added percentage to any one decile necessitates a corresponding loss to some others. An area outside of the square which represents the theoretical distribution could be transferred to the vacant area inside of the square, giving a diagram as in Fig. 1, A.

Some of the marked irregularities in the profiles of the

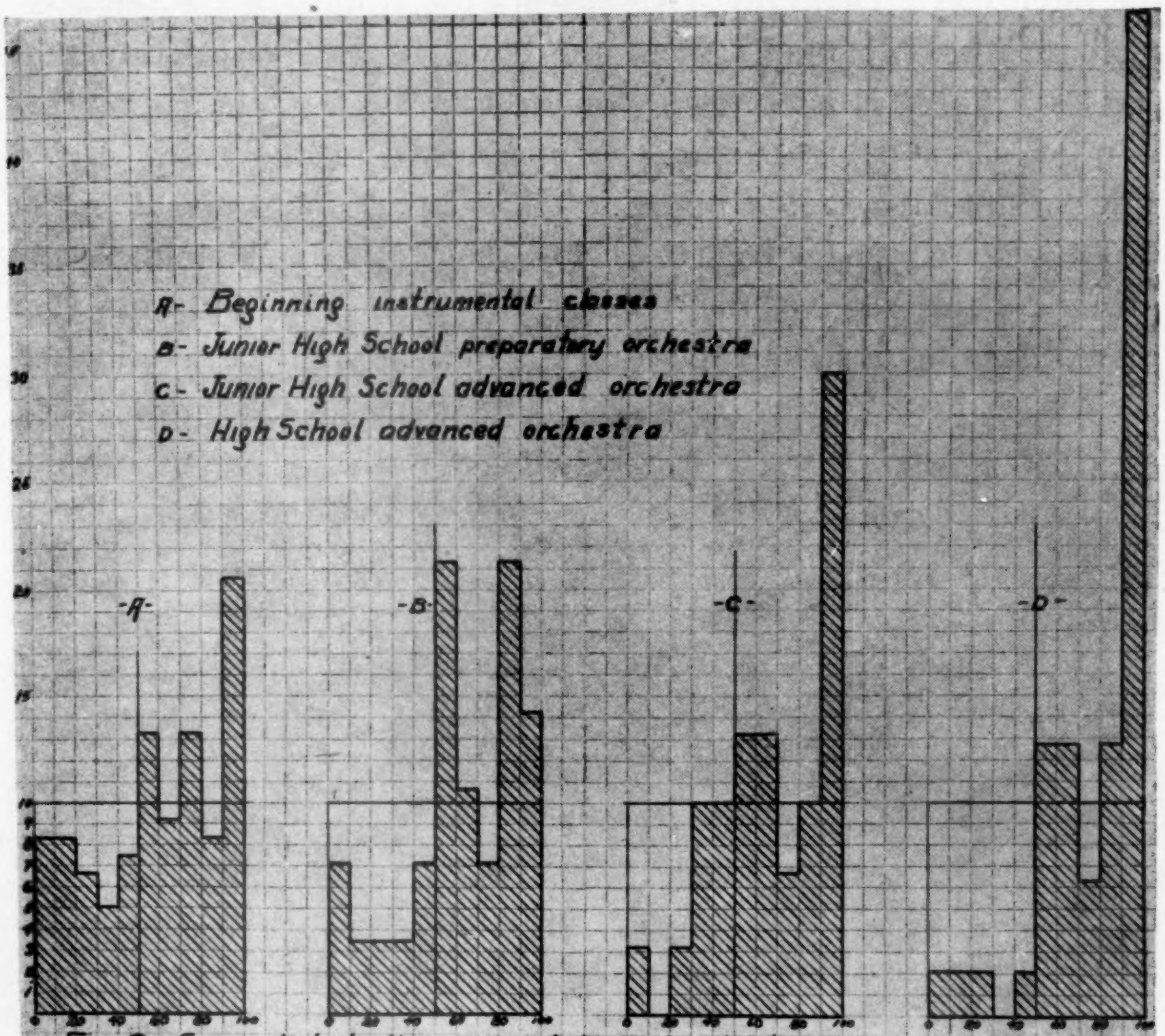



FIG. 2- Group distributions on pitch test x axis : Range in Percentiles

histograms which follow are due, no doubt, to the relatively small numbers in some of the instrumental groups. These irregularities could have been largely reduced by smoothing, but in this case, the unsmoothed graph is sufficient to show the general skewness of the distribution. Since the histogram was selected in preference to the frequency polygon in order more accurately to present the results of the tests as found in each decile in terms of area, smoothing would be inconsistent with the plan.

*Distributions of scores.* Tables II to VII present group dis-

tributions of the scores on pitch, intensity, time, consonance, tonal memory, and rhythm, respectively. In order to represent these data in form for comparison with the theoretical diagram previously explained, the data in each table are presented in graphic form, each table having its corresponding graph.

1. *Pitch.* Fig. 2 shows group distributions of the results of the pitch test. Diagram A represents the results in the sense of pitch of the 121 pupils from the eight beginning instrumental classes. There is an evident skewness to the left, the concentration of cases being particularly noticeable in the tenth decile. The vacant area in the upper left hand portion of the diagram denotes a decreased percentage below the average of the unselected group. Table II gives the percentages. The graph indicates that this beginning instrumental group is slightly above average in the sense of pitch.

TABLE II. *Showing group distributions on pitch test*

| Percentile Scores | Beg. Instr. Classes | | Jr. H. S. Prep. Orch. | | Jr. H. S. Adv. Orch. | | H. S. Adv. Orch. | |
|---|---|---|---|---|---|---|---|---|
| | F* | %† | F | % | F | % | F | % |
| 90–100 | 25 | 20.7 | 4 | 14.3 | 9 | 30.0 | 22 | 46.8 |
| 80– 89 | 10 | 8.3 | 6 | 21.4 | 3 | 10.0 | 6 | 12.8 |
| 70– 79 | 16 | 13.2 | 2 | 7.1 | 2 | 6.7 | 3 | 6.4 |
| 60– 69 | 11 | 9.1 | 3 | 10.7 | 4 | 13.3 | 6 | 12.8 |
| 50– 59 | 16 | 13.2 | 6 | 21.4 | 4 | 13.3 | 6 | 12.8 |
| 40– 49 | 9 | 7.4 | 2 | 7.1 | 3 | 10.0 | 1 | 2.1 |
| 30– 39 | 6 | 5.0 | 1 | 3.6 | 3 | 10.0 | 0 | 0.0 |
| 20– 29 | 8 | 6.6 | 1 | 3.6 | 1 | 3.3 | 1 | 2.1 |
| 10– 19 | 10 | 8.3 | 1 | 3.6 | 0 | 0.0 | 1 | 2.1 |
| 0– 9 | 10 | 8.3 | 2 | 7.1 | 1 | 3.3 | 1 | 2.1 |
| | 121 | | 28 | | 30 | | 47 | |

* F means frequencies.
† % means the per cent of the group falling within a given decile.

Diagram D presents the results of the high school advanced orchestra in the sense of pitch. Practically all of the cases rank above average in this capacity. The large number of scores that were made in the tenth decile is chiefly responsible for the small percentage of cases below average, for the other deciles are, on the whole, but slightly above normal. Table II indicates that nearly half of the cases falls in this highest division.

Diagrams A and D, then, give a comparison of the distribution in the sense of pitch of a large group of beginning instrumental students with that of the most advanced instrumental organization in the school system in terms of a theoretical distribution. The grouping of the beginning class in this capacity deviates but slightly from the normal while the distribution of the high school advanced orchestra shows a very marked negative skewness with a large percentage of cases at the upper limit and with very few ranking below average.

Fig. 2 also shows the distributions of the scores made in the pitch test by the two junior high school orchestras. Considering all four groups we may notice that there is an increased negative skewness in each succeeding stage. This is particularly pronounced because of the decreasing percentage of cases at the very lower limit and the increasing percentage at the upper limit.

Table II shows that 35.6 per cent of the cases in the beginning instrumental classes fall below the average of a theoretical distribution. The next group, the junior high school preparatory orchestra, shows 25.0 per cent below average. The junior high school advanced orchestra has 26.6 per cent below the average but 20 of this 26.6 per cent is between the 30th and 50th percentiles, leaving only 6.6 per cent in the lower percentiles, 0 to 30, as compared with the 14.3 per cent in these low percentiles for the junior high school preparatory orchestra. In the beginning groups, 23.2 per cent are in this low range. In the last group, the high school advanced orchestra, there is the greatest negative skewness,—only 8.4 per cent of this group ranking below average and the very large percentage of cases, 46, falling at the very upper limit of the range.

2. *Intensity.* The results of the four groups in the intensity test are similarly presented in Fig. 3. The beginning instrumental classes tend to be distributed quite evenly over the entire range. The graph of the junior high school preparatory orchestra shows some evidence of the " bunching " of the talent in this capacity along the central deciles. The increase found in this range is at the expense of the percentages at the lower limit, for the increase in the tenth decile is nearly offset by the decrease from the normal

in the ninth decile, so that it may be considered that the upper range of this group is about normal.

The graph of the junior high school advanced orchestra, Fig. 3, C, in comparison with the preparatory orchestra, Fig. 3, B, shows that the area of concentration has shifted further to the right, again at the expense of the lower range. Fig. 3, D, the graph of the high school advanced orchestra, shows a more

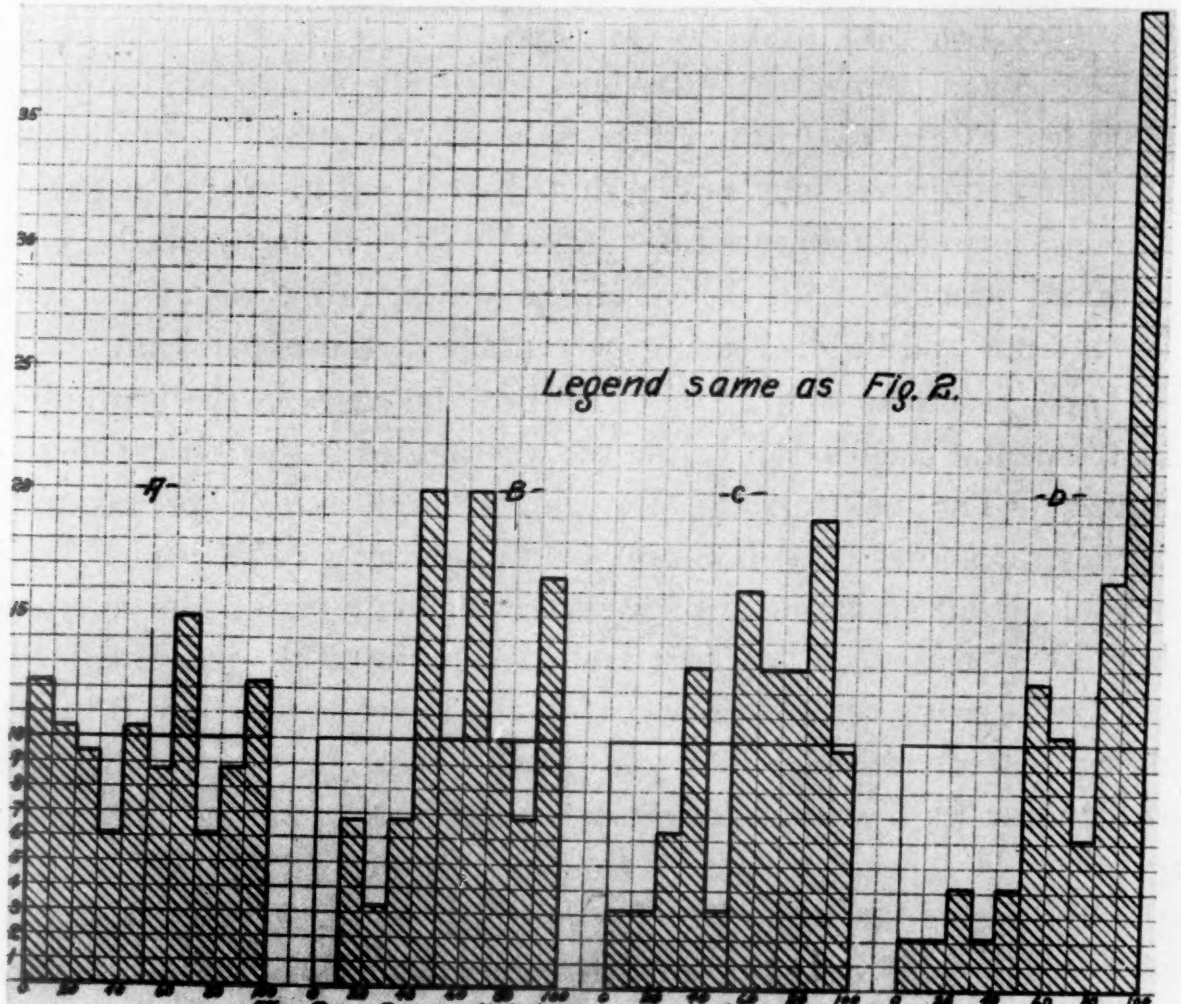



Fig. 3— Group distributions on intensity test

decided increase in this capacity by a still greater shift toward the higher divisions, the greatest concentration of cases being near the extreme upper limit of the range, as was found in the pitch test. In this organization there is also the similarity in pitch and intensity in that the distributions are extremely low throughout the lower half of the range. The percentages in the lower half of the range in intensity, however, are not quite so low as in pitch, for there are 14.7 per cent making scores below average in intensity and only 8.4 per cent falling below average

in pitch. An observation of Figs. 2 and 3 show that there is the same general tendency in the tests of these two capacities at the different levels of achievement. The beginning instrumental classes rank about normal or slightly above throughout the range in both tests. There is a slight increase in both pitch and intensity in the junior high school preparatory orchestra, and a still greater increase in the junior high school advanced orchestra. With the high school advanced orchestra a very large percentage of cases occur at the upper limit in both pitch and intensity. Although a comparison of these two charts shows a general similarity in the shifting of the distributions of these two capacity-tests at each level of achievement, it seems, however, that on the whole these groups rank a little higher in pitch than in intensity at these various levels.

TABLE III. *Showing group distributions on intensity test*

| Percentile Scores | Beg. Instr. Classes | | Jr. H. S. Prep. Orch. | | Jr. H. S. Adv. Orch. | | H. S. Adv. Orch. | |
|---|---|---|---|---|---|---|---|---|
| | F* | %† | F | % | F | % | F | % |
| 90–100 | 14 | 12.3 | 5 | 16.7 | 3 | 9.7 | 19 | 39.6 |
| 80– 89 | 10 | 8.8 | 2 | 6.7 | 6 | 19.0 | 8 | 16.7 |
| 70– 79 | 7 | 6.1 | 3 | 10.0 | 4 | 12.9 | 3 | 6.2 |
| 60– 69 | 17 | 14.9 | 6 | 20.0 | 4 | 12.9 | 5 | 10.4 |
| 50– 59 | 10 | 8.8 | 3 | 10.0 | 5 | 16.1 | 6 | 12.5 |
| 40– 49 | 12 | 10.5 | 6 | 20.0 | 1 | 3.2 | 2 | 4.2 |
| 30– 39 | 7 | 6.1 | 2 | 6.7 | 4 | 12.9 | 1 | 2.1 |
| 20– 29 | 11 | 9.6 | 1 | 3.3 | 2 | 6.4 | 2 | 4.2 |
| 10– 19 | 12 | 10.5 | 2 | 6.7 | 1 | 3.2 | 1 | 2.1 |
| 0– 9 | 14 | 12.3 | 0 | 0.0 | 1 | 3.2 | 1 | 2.1 |
| | 114 | | 30 | | 31 | | 48 | |

* F means frequencies.
† % means the per cent of the group falling within a given decile.

3. *Time.* In Fig. 4 are given the diagrams of the distributions of these same four groups in the time test. In diagram A, it is seen that the distribution of the beginning instrumental class deviates but slightly from the normal. The slight irregularities outside the square are offset by those inside. In contrast with this even distribution are those found in the next two diagrams. There is a decided positive skewness found in the graph of the preparatory orchestra. The upper deciles are but partly filled while some of the lower deciles are far above their normal height.

Because of the small number of cases in this group, part of this extreme "bunching" of cases in the first and third deciles may be attributed to errors in sampling, for the neighboring deciles are below normal in size. The total absence of cases in the fifth and tenth deciles add to the irregularity of the contour of this graph. But everything considered, there is a concentration in the lower half of the range. The graph of the junior high school advanced orchestra in time, as shown in C of Fig. 4, is about as

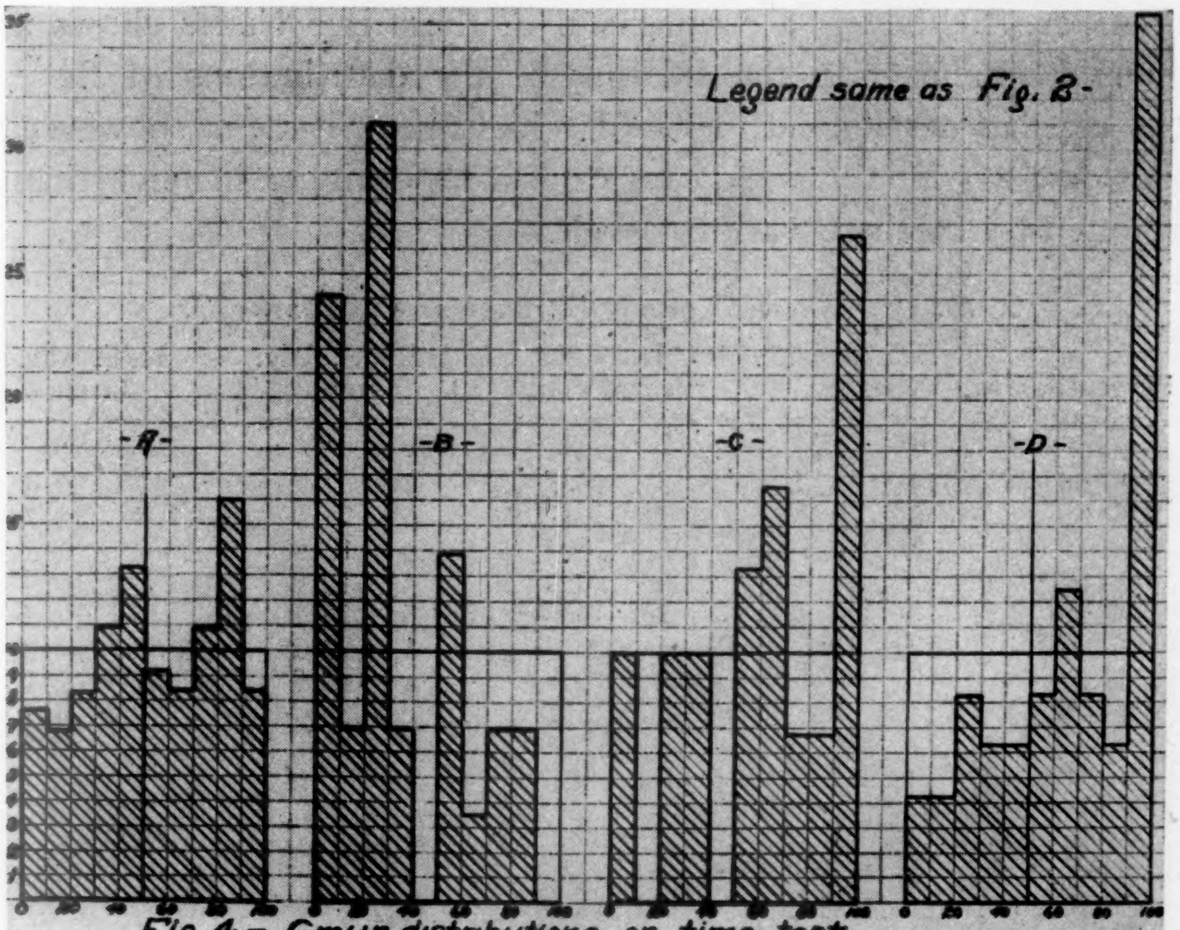



Fig. 4 — Group distributions on time test

irregular as the preceding one that has just been discussed. But instead of a large positive skewness, the distribution of this group is greatly skewed to the left. The second and fifth deciles show an entire absence of cases while Table IV shows that there are 26.7 per cent of the cases in the highest decile. Diagram D in this figure, in representing the high school advanced orchestra in the time test, shows a large number of cases falling in the tenth decile as was found in the tests of pitch and intensity, although there is not quite so large a percentage of cases in this division as was found in the other two tests. The upper four deciles in the upper

half of the range, as a whole, are but slightly below normal, indicating that the large percentage of cases in the tenth decile is grouped there at the expense of the lower deciles, which show a decrease in all of the divisions. Although this negative skewness is greater than that of the other three classes considered in this figure, it proves to be less than it is in the pitch and intensity distributions for this orchestra.

TABLE IV. *Showing group distributions on time test*

| Percentile Scores | Beg. Instr. Classes | | Jr. H. S. Prep. Orch. | | Jr. H. S. Adv. Orch. | | H. S. Adv. Orch. | |
|---|---|---|---|---|---|---|---|---|
| | F* | %† | F | % | F | % | F | % |
| 90–100 | 10 | 8.4 | 0 | 0.0 | 8 | 26.7 | 17 | 35.4 |
| 80– 89 | 19 | 16.0 | 2 | 6.9 | 2 | 6.7 | 3 | 6.3 |
| 70– 79 | 13 | 10.9 | 3 | 6.9 | 2 | 6.7 | 4 | 8.3 |
| 60– 69 | 10 | 8.4 | 1 | 3.4 | 5 | 16.7 | 6 | 12.5 |
| 50– 59 | 11 | 9.2 | 4 | 13.8 | 4 | 13.3 | 4 | 8.3 |
| 40– 49 | 16 | 13.4 | 0 | 0.0 | 0 | 0.0 | 3 | 6.3 |
| 30– 39 | 13 | 10.9 | 2 | 6.9 | 3 | 10.0 | 3 | 6.3 |
| 20– 29 | 10 | 8.4 | 9 | 31.0 | 0 | 0.0 | 4 | 8.3 |
| 10– 19 | 8 | 6.7 | 2 | 6.9 | 3 | 10.0 | 2 | 4.2 |
| 0– 9 | 9 | 7.6 | 7 | 24.1 | 0 | 0.0 | 2 | 4.2 |
| | 119 | | 29 | | 27 | | 48 | |

* F means frequencies.
† % means the per cent of the group falling within a given decile.

4. *Consonance.* In Fig. 5 are found the diagrams of the four organizations in the consonance test. The beginning instrumental group shows a distribution in which the third and tenth deciles have a considerable number more than the normal for these divisions. The other deciles in each half of this distribution, however, are sufficiently below normal to offset most of this irregularity and the skewness, if any, is negligible. Fig. 5, B, shows a negative skewness for the junior high school preparatory orchestra in this capacity. The upper deciles of the lower half of the range show a considerable " bunching " of the cases in this region and there is a decrease from the normal number of cases in the upper range. This condition is reversed in the junior high school advanced orchestra as shown by C of Fig. 5. There is a decided absence of cases in the lower decile with a bunching of cases along the upper four deciles, causing the distribution to show a marked negative skewness. In the distribution of the

high school advanced orchestra, a negative skewness is even more evident. Again in this test, a large number of the members of the orchestra made scores in the tenth decile. Reference to Table

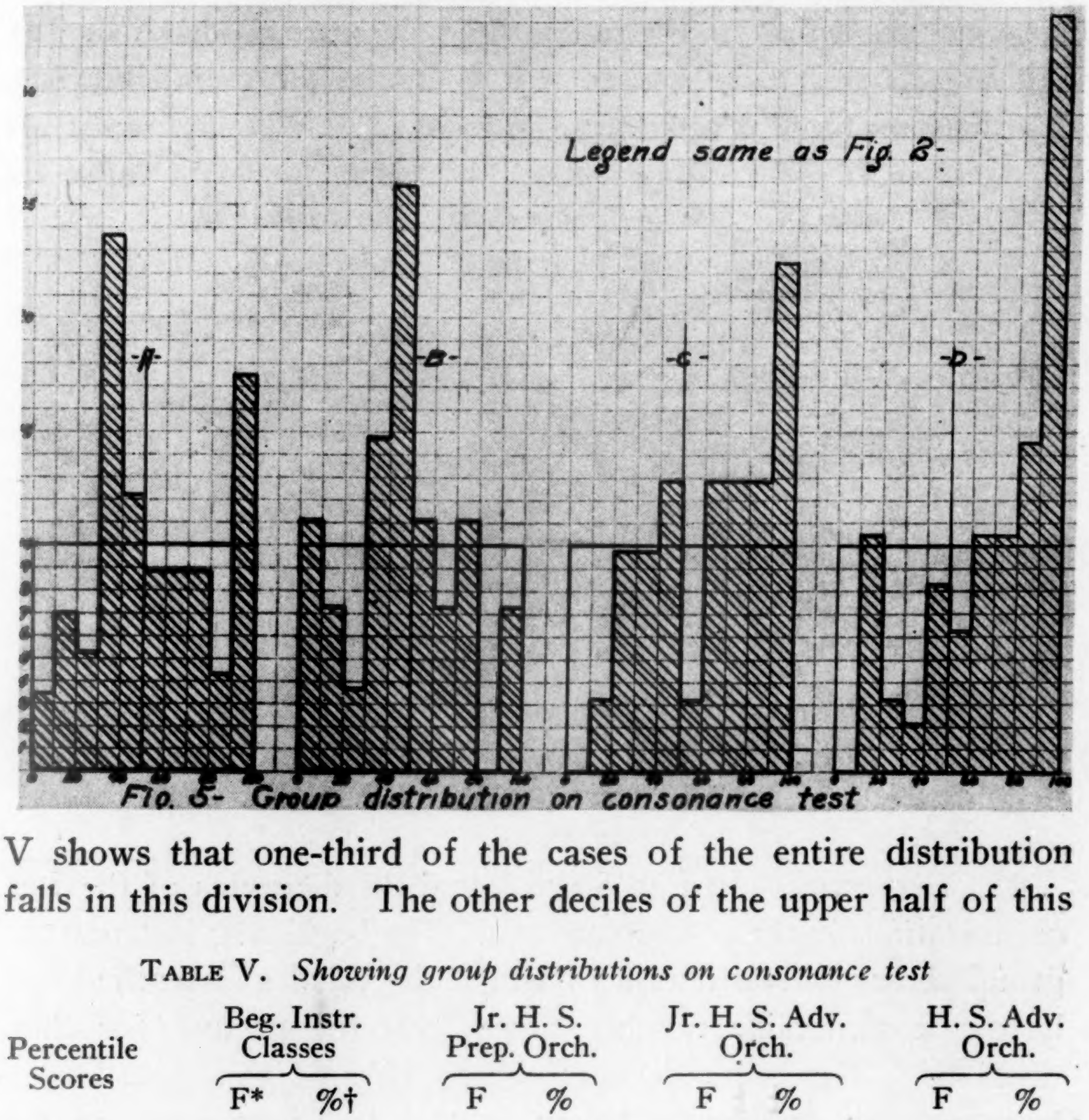



Fig. 5- Group distribution on consonance test

V shows that one-third of the cases of the entire distribution falls in this division. The other deciles of the upper half of this

TABLE V. *Showing group distributions on consonance test*

| Percentile Scores | Beg. Instr. Classes F* | Beg. Instr. Classes %† | Jr. H. S. Prep. Orch. F | Jr. H. S. Prep. Orch. % | Jr. H. S. Adv. Orch. F | Jr. H. S. Adv. Orch. % | H. S. Adv. Orch. F | H. S. Adv. Orch. % |
|---|---|---|---|---|---|---|---|---|
| 90–100 | 20 | 17.5 | 2 | 7.4 | 7 | 22.6 | 16 | 33.3 |
| 80– 89 | 5 | 4.4 | 0 | 0.0 | 4 | 12.9 | 7 | 14.6 |
| 70– 79 | 10 | 8.8 | 3 | 11.1 | 4 | 12.9 | 5 | 10.4 |
| 60– 69 | 10 | 8.8 | 2 | 7.4 | 4 | 12.9 | 5 | 10.4 |
| 50– 59 | 10 | 8.8 | 3 | 11.1 | 1 | 3.2 | 3 | 6.3 |
| 40– 49 | 14 | 12.3 | 7 | 25.9 | 4 | 12.9 | 4 | 8.3 |
| 30– 39 | 27 | 23.7 | 4 | 14.8 | 3 | 9.7 | 1 | 2.1 |
| 20– 29 | 6 | 5.3 | 1 | 3.7 | 3 | 9.7 | 2 | 4.2 |
| 10– 19 | 8 | 7.0 | 2 | 7.4 | 1 | 3.2 | 5 | 10.4 |
| 0– 9 | 4 | 3.5 | 3 | 11.1 | 0 | 0.0 | 0 | 0.0 |
| | 114 | | 27 | | 31 | | 48 | |

* F means frequencies.
† % means the per cent of the group falling within a given decile.

range are well filled and the " bunching " of cases near the upper limit of the range is at the expense of the lower half of the range.

5. *Tonal Memory.* The diagrams of these four groups in tonal memory, as shown in Fig. 6, disclose extreme variations. The distribution of the beginning instrumental classes is somewhat skewed to the right as shown in the first diagram of this figure. Diagram B representing the distribution of the junior high school

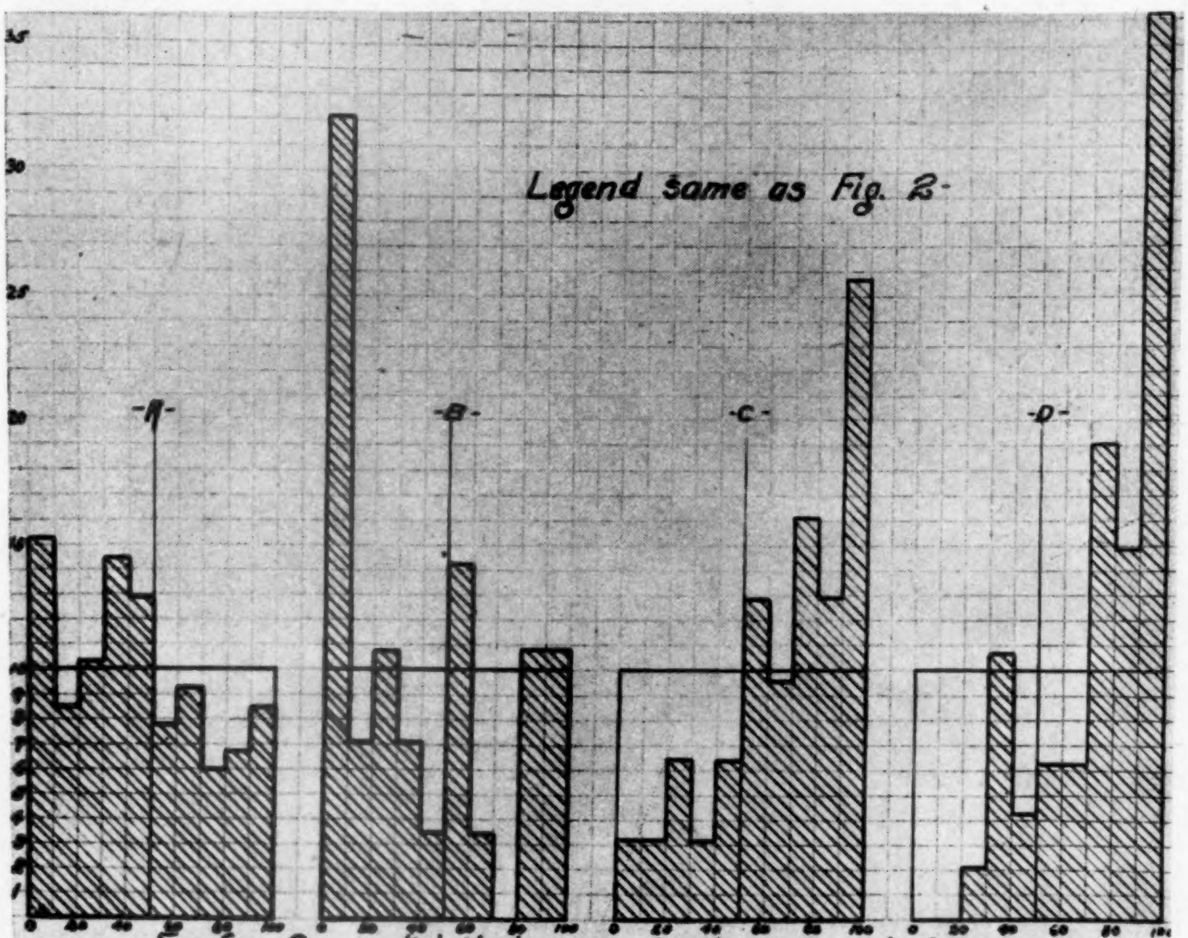



Fig. 6— Group distributions on tonal memory test

preparatory orchestra in this capacity, shows a radical positive skewness. A large number of cases fall at the lower part of the range. The two highest deciles have their normal percentages, but below these two deciles there is a scarcity of cases which allows for the high percentages at the lower extremes.

In contrast to this extreme skewness to the right is that of the distribution of the junior high school advanced orchestra with its negative skewness, as shown in C of Fig. 6. The grouping is more regular, however, in its deviations from the normal, starting with a marked decrease in percentages of cases at the

lower part of the range and ascending gradually, finally reaching the greatest percentage of cases in the tenth decile. An extremely large concentration of cases occurs at the right of the distribution of the high school orchestra as shown in D of Fig. 6. With but very few cases in the lower third of the distribution and a very great number of cases in the upper three deciles, this distribution has one of the greatest deviations from the normal. Table VI indicates that 70 per cent of the cases fall above the seventieth percentile with over one-third of the cases found in the tenth decile again in this test.

TABLE VI. *Showing group distributions on tonal memory test*

| Percentile Scores | Beg. Instr. Classes F* | %† | Jr. H. S. Prep. Orch. F | % | Jr. H. S. Adv. Orch. F | % | H. S. Adv. Orch. F | % |
|---|---|---|---|---|---|---|---|---|
| 90–100 | 10 | 8.5 | 3 | 10.7 | 8 | 25.8 | 17 | 36.2 |
| 80– 89 | 8 | 6.8 | 3 | 10.7 | 4 | 12.9 | 7 | 14.9 |
| 70– 79 | 7 | 6.0 | 0 | 0.0 | 5 | 16.1 | 9 | 19.1 |
| 60– 69 | 11 | 9.4 | 1 | 3.6 | 3 | 9.7 | 3 | 6.4 |
| 50– 59 | 9 | 7.7 | 4 | 14.3 | 4 | 12.9 | 3 | 6.4 |
| 40– 49 | 15 | 12.8 | 1 | 3.6 | 2 | 6.5 | 2 | 4.3 |
| 30– 39 | 17 | 14.5 | 2 | 7.1 | 1 | 3.2 | 5 | 10.6 |
| 20– 29 | 12 | 10.3 | 3 | 10.7 | 2 | 6.5 | 1 | 2.1 |
| 10– 19 | 10 | 8.5 | 2 | 7.1 | 1 | 3.2 | 0 | 0.0 |
| 0– 9 | 18 | 15.4 | 9 | 32.1 | 1 | 3.2 | 0 | 0.0 |
| | 117 | | 28 | | 31 | | 47 | |

* F means frequencies.
† % means the per cent of the group falling within a given decile.

6. *Rhythm.* In A of Fig. 7 is found the diagram for the beginning instrumental class in rhythm. A slight negative skewness is evident for the group in this capacity. It is particularly noticeable because of the large percentage of cases in the eighth decile. Likewise a negative skewness appears in the distribution of the junior high school preparatory orchestra in this test as shown in B of this figure. The largest grouping is around the central deciles with a decrease in percentage of cases at both the upper and lower parts of the range. This is particularly true at the lower part of the distribution and as a result there is a slight skewness to the left. This negative skewness is greater in diagram C of Fig. 7, which represents the distribution of the junior high school advanced orchestra in the rhythm test. There is a decided bunching of the cases along the upper half of the

range, which is particularly noticeable in the tenth decile. In the distribution of the high school advanced orchestra, Fig. 7, D, there is again a very great negative skewness with a very large percentage of cases above the fiftieth percentile and only a

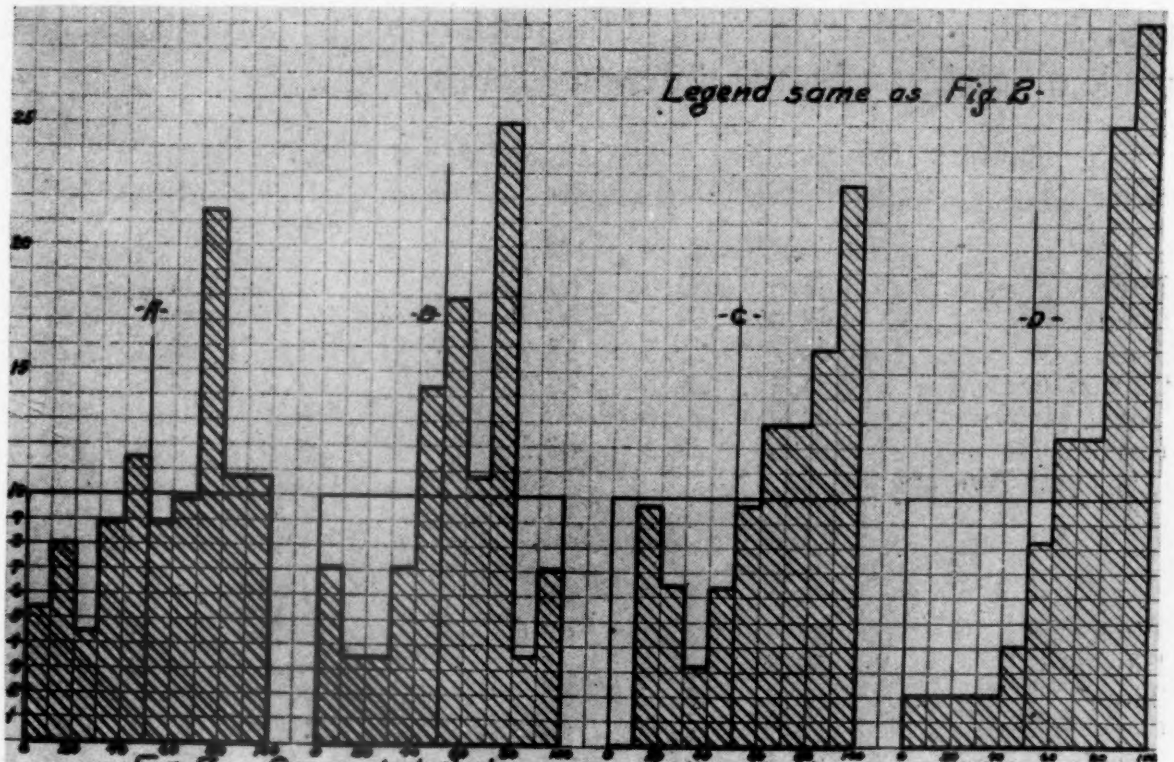



Fig. 7— Group distributions on rhythm test

relatively small percentage below. Table VII shows that 87.5 per cent of the cases are in the upper half of the range, 54.2 per cent falling within the ninth and tenth deciles.

TABLE VII. *Showing group distributions on rhythm test*

| Percentile Scores | Beg. Instr. Classes | | Jr. H. S. Prep. Orch. | | Jr. H. S. Adv. Orch. | | H. S. Adv. Orch. | |
|---|---|---|---|---|---|---|---|---|
| | F* | %† | F | % | F | % | F | % |
| 90–100 | 12 | 10.7 | 2 | 7.1 | 7 | 22.6 | 14 | 29.2 |
| 80– 89 | 12 | 10.7 | 1 | 3.6 | 5 | 16.1 | 12 | 25.0 |
| 70– 79 | 24 | 21.4 | 7 | 25.0 | 4 | 12.9 | 6 | 12.5 |
| 60– 69 | 11 | 9.8 | 3 | 10.7 | 4 | 12.9 | 6 | 12.5 |
| 50– 59 | 10 | 8.9 | 5 | 17.9 | 3 | 9.7 | 4 | 8.3 |
| 40– 49 | 13 | 11.6 | 4 | 14.3 | 2 | 6.5 | 2 | 4.2 |
| 30– 39 | 10 | 8.9 | 2 | 7.1 | 1 | 3.2 | 1 | 2.1 |
| 20– 29 | 5 | 4.5 | 1 | 3.6 | 2 | 6.5 | 1 | 2.1 |
| 10– 19 | 9 | 8.0 | 1 | 3.6 | 3 | 9.7 | 1 | 2.1 |
| 0– 9 | 6 | 5.4 | 2 | 7.1 | 0 | 0.0 | 1 | 2.1 |
| | 112 | | 28 | | 31 | | 48 | |

* F means frequencies.
† % means the per cent of the group falling within a given decile.

Up to this point in the presentation a general increase in negative skewness with each more advanced group has been found.

*Data in terms of central tendency.* The fact of negative skewness may be further indicated by presenting the data in terms of measures of central tendency. Table VIII presents the average, the standard deviation and the median of the percentile scores made on each test by the different groups.

TABLE VIII. *Showing Av., S.D., and M. of scores in all tests*

| | Beg. Instr. Classes | | | Jr. H. S. Prep. Orch. | | |
|---|---|---|---|---|---|---|
| | Av. | S.D. | M. | Av. | S.D. | M. |
| Pitch | 57.6 | 30.0 | 60.9 | 61.3 | 26.4 | 62.8 |
| Intensity | 49.0 | 29.7 | 50.5 | 59.9 | 25.3 | 61.2 |
| Time | 51.7 | 27.5 | 52.7 | 31.9 | 25.3 | 25.6 |
| Consonance | 54.4 | 26.8 | 46.6 | 47.7 | 24.5 | 44.5 |
| Tonal Memory | 44.2 | 27.6 | 40.5 | 39.1 | 32.5 | 29.5 |
| Rhythm | 55.6 | 27.6 | 62.2 | 54.0 | 23.8 | 57.5 |
| General Average | 52.1 | | | 49.1 | | |

| | Jr. H. S. Adv. Orch. | | | H. S. Adv. Orch. | | |
|---|---|---|---|---|---|---|
| | Av. | S.D. | M. | Av. | S.D. | M. |
| Pitch | 67.4 | 25.1 | 67.0 | 77.4 | 22.6 | 87.0 |
| Intensity | 59.4 | 24.6 | 63.3 | 73.5 | 24.2 | 83.3 |
| Time | 60.3 | 26.4 | 66.5 | 65.9 | 28.8 | 69.5 |
| Consonance | 64.9 | 25.7 | 68.3 | 71.0 | 27.2 | 77.5 |
| Tonal Memory | 67.1 | 25.9 | 72.5 | 75.1 | 21.3 | 86.6 |
| Rhythm | 64.6 | 26.3 | 70.8 | 76.3 | 22.1 | 81.2 |
| General Average | 66.0 | | | 73.2 | | |

A comparison of the averages of these four groups in each of the six tests may be made by referring to Figs. 8 to 13 inclusive. The horizontal line denotes the fiftieth percentile, marking a point that a representative average talent would reach. It is seen that the beginning classes in instrumental music average somewhat above the mean of the percentile range in pitch, rhythm, and consonance in the order named. The average of these classes is very close around the mean of the range in intensity and time, and falls somewhat below this mean in tonal memory.

The averages of the junior high school advanced orchestra decidedly excels the averages of the junior high school preparatory orchestra in all the tests with the exception of that of intensity, in which the averages for the two orchestras are practically the same. The averages of the junior high school preparatory orchestra noticeably fall below the averages of the beginning instrumental classes in time, consonance, and tonal memory. The

average of the junior high school preparatory orchestra exceeds the average of the beginning instrumental groups in pitch and intensity, and is about the same in rhythm.

The averages of the high school advanced orchestra greatly exceed any of the other groups in all six of the Seashore tests with high averages of 77.4, 73.5, 65.9, 71.0, 75.1, and 76.3 in the tests of pitch, intensity, time, consonance, tonal memory, and rhythm, respectively.

In Fig. 14 the combined averages of the percentile scores made by the four groups in all six tests shows an average of 52.1 for the beginning instrumental classes, 49.1 for the junior high school preparatory orchestra, 66.0 for the junior high school advanced orchestra, and 73.2 for the high school advanced orchestra.

### III. Interpretations

*Beginning instrumental classes.* From a review of the group distributions represented in Figs. 2 to 14, it is evident that there is a wide variation in the concentration of cases and in the averages of the various groups in the different tests. In the beginning instrumental classes, the averages in the six tests appear to be about normal, *i.e.,* about the same as would be found in an unselected group, as portrayed by the theoretical distribution of percentiles in Fig. 1, A. Evidently, from these averages, the predisposition to avail themselves of special instruction in instrumental music can not be attributed to special talent in music. The average in the six Seashore tests of 52.1 could hardly be considered enough above the mean percentile range to be a significant reason for the 125 students of these beginning instrumental classes to elect special courses in music. So low an average for beginning instrumental classes would probably not be found in a newly-organized instrumental program, but in a school system in which class instruction is so general, some of the usual reasons of lesser importance for undertaking special instrumental instruction such as the impetuousness of the child, the inclination or wishes of the parent for the child to study instrumental music, or the ability of the home to furnish the child with an instrument could be given as much weight. Since the average in the tests of six innate capacities results in an average corresponding to

that of a chance sampling, under this method of organization of instrumental music classes, it follows that the membership of a beginning instrumental class is not affected by a choice of the talented for this work but is a chance affair. However, an examination of the averages of the different tests tempers this judgment to some extent. This pertains particularly to the pitch and rhythm tests in which the averages of these eight beginning instrumental groups are 57.6 and 55.6 respectively. Although these averages are but slightly above those which the entire school would be expected to make, nevertheless, this increase of 7.6 and 5.6 is enough to justify the conclusion that a natural aptitude in these two capacities is of some slight influence, as is commonly assumed, in determining the students who elect the beginning instrumental courses. The averages in intensity, time, and consonance fall closely around the normal average, and so the personnel of these instrumental classes has not been influenced by a natural aptitude in these capacities. The average of 44.2 in tonal memory appears to be low. Reference to the distribution in this test for this group, Fig. 6, A, shows that the concentration of cases in the lowest decile, where there would be the greatest influence on an average, is largely accountable for this average. Since the concentration is in the lowest decile, this irregularity seemingly is explainable on the basis of lack of understanding of the test by a few students.

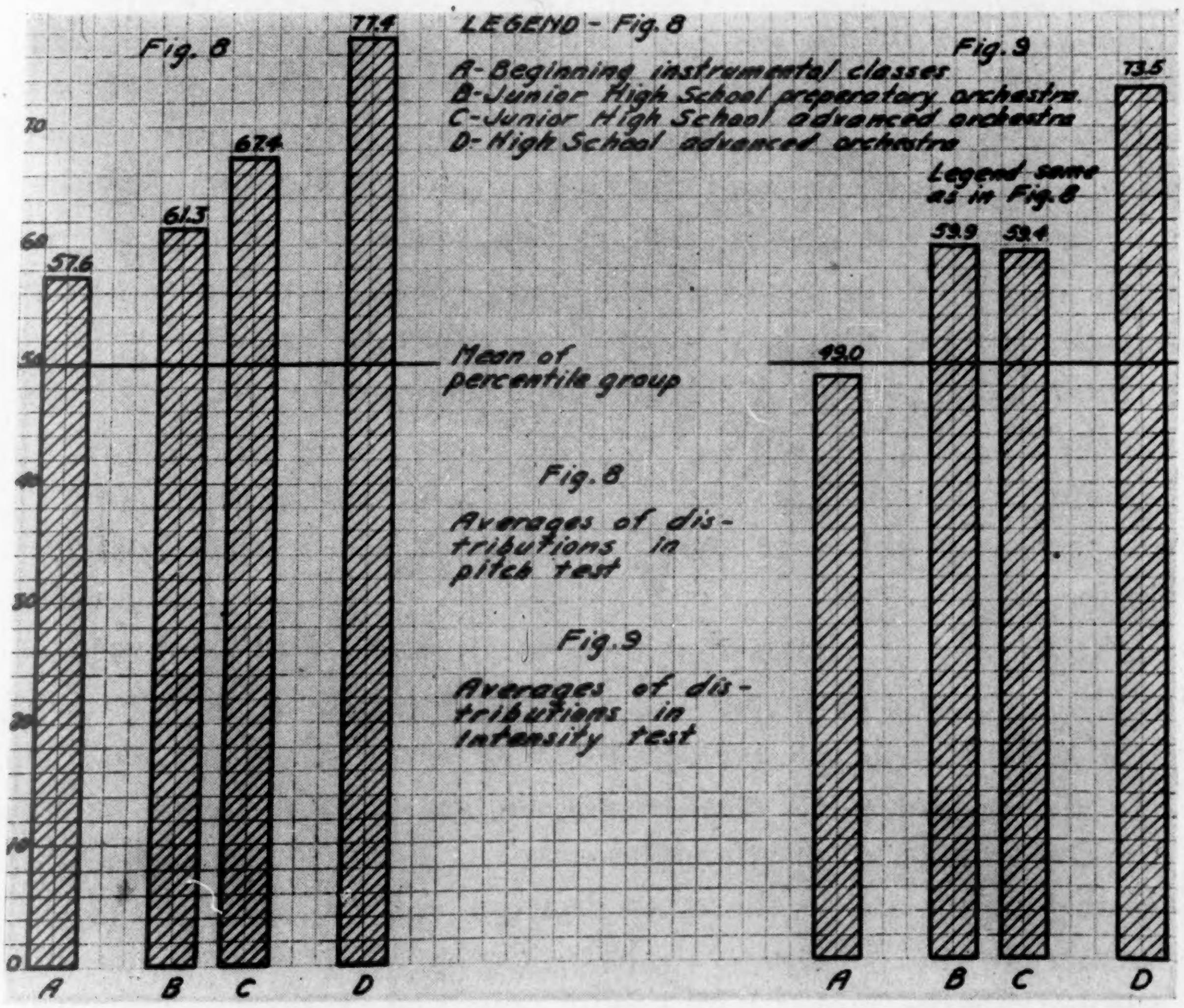
*The high school advanced orchestra.* In turning from the averages of the beginning instrumental classes to the averages of the high school advanced orchestra, the group at the highest level of achievement in the instrumental department of this school system, a very marked difference is seen. Instead of averages comparatively close about the fiftieth percentile, there is found an increase in the averages of all of the tests, ranging from 15 to 27 above the fiftieth percentile mark. The combined average of the six tests, as shown in Fig. 14, D, is 73.2. This increase in averages of capacities is very likely the result of a long process of selection of those with higher musical capacities. From the results of the tests of the beginning instrumental classes, it seems reasonable to assume that the averages of the beginning instru-

mental classes, at the time the members of the high school advanced orchestra were beginners, were likewise somewhere close to the fiftieth percentile. At various times between this beginning stage and their present position as members of the high school advanced orchestra, there must have been a loss of students of lower ranking in these capacity tests in order to account for the increase in the percentile averages of those who remain. Since the members of the high school advanced orchestra are selected on the basis of their ability to perform, it is reasonable to conclude, judging from the averages of the high school advanced orchestra in comparison with the averages of the beginning instrumental classes, that the capacities of musical talent, as measured by the Seashore tests, have been an influence in the selection of the membership of this orchestra; and that groups at intermediate stages of advancement have been correspondingly affected.

*Comparison of all groups.* A closer examination of the results of the tests at different levels of achievement supports this conclusion.

*Pitch.* Fig. 8, shows that there is an increase in the averages of the four groups in pitch at each higher stage of ability. As previously stated, the average of 57.6 is enough above average to indicate that pitch may be considered a slight factor in the decision to take up instrumental music. In the courses following this beginning course, there is a division of those who register for further work. Those who have made the best progress are selected for the junior high school advanced orchestra, and those who are not so proficient on their instrument are placed in the junior high school preparatory orchestra. It has been found that 61.3 is the average score of the junior high school preparatory orchestra while 67.4 is the average for the junior high school advanced orchestra. Both of these averages are higher than the average of the beginning instrumental classes. It seems that in both cases there has been a selection of the students who have made the higher scores in pitch; and this must mean that students who have made the lower scores have a tendency to discontinue. These averages, then, tend to show that the capacity

for pitch discrimination is not only a determining factor for differentiation of ability to perform, as shown by the difference in the averages of these two junior high school orchestras, but also it is a selective factor, as shown in both of these junior high school orchestras by a comparison of their combined averages with the average of the beginning instrumental classes.




The capacity for pitch discrimination must have been partly responsible for a still finer selection by the time the students are eligible for the high school advanced orchestra, as judged by the high average of 77.4 in this capacity. Further evidence showing that there is a tendency for pitch discrimination to affect ability in performance is the fact of the increasing negative skewness of the distribution at each higher level of achievement. This is forcibly brought out by the fact (see Table II), that 46.8 per cent of the cases in the high school advanced orchestra scored in the tenth decile in this test.

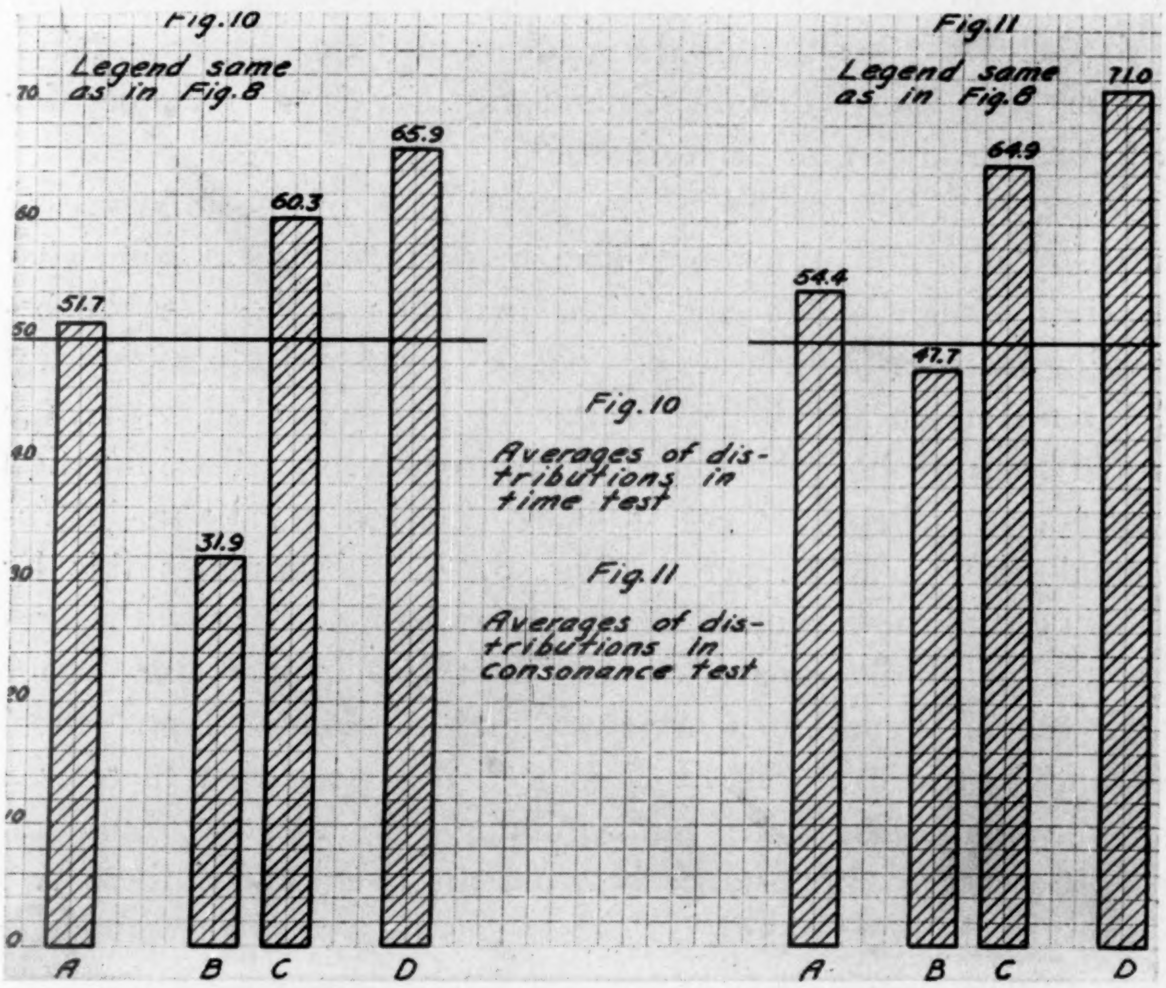
Table VIII shows that there is an increased value in the medians for each group of higher ability. The median for the beginning instrumental group in pitch is 60.9, and that for the junior high school preparatory orchestra, 62.8. The median for the junior high school advanced orchestra in this test is 67.0, while that for the high school advanced orchestra rises to 87.0. The fact that 50 per cent of the members of the high school advanced orchestra score above 87.0 is of special significance. This increasing position of the medians in these percentile distributions also shows that this innate capacity is an influence for determining ability in performance.

*Intensity.* In considering the possibilities of the influence of intensity discrimination on ability in performance, a somewhat different situation is found. The average of 49.0 for the beginning instrumental classes can not be considered as a significant difference from the fiftieth percentile division. This average would seem to show that the capacity for intensity discrimination was not an influence in the students' decision to take up instrumental music. Reference to Fig. 3, A, substantiates this by showing that there is quite an even distribution of cases throughout the percentile range. In the next two groups, the junior high school preparatory orchestra and the junior high school advanced orchestra, Fig. 9, B and C, it is seen that there is a significant increase above the beginning instrumental groups but no difference of importance between the averages of these two groups of different abilities. This seems to signify that intensity discrimination is of importance as a determinant for continuation of the instrumental work beyond the beginning stage but is not of significance for a distinction in the selection for these two more advanced groups of differing abilities. The distributions of these groups, Fig. 3, B and C, also tend to show this by the sparseness of cases in the lower deciles and a concentration of cases around and above the average of the percentile range.

In D of Fig. 9, it is found that the high school advanced orchestra has the high average of 73.5 in intensity. This indicates that the capacity for intensity discrimination is another factor influencing the selection of those with higher abilities to perform,

and is in accord with *Seashore's* statement (**14**, p. 102) that "The effective performer is limited by his capacity for precision in the hearing of the shades of stress which he seeks to convey."

The percentile distribution of this highest group in the intensity test, Fig. 3, D, shows a distinct concentration of cases in the upper deciles and a sparseness of cases in the lower half of the range. Table III gives 56.3 as the percentage of cases in the two




highest deciles. The median for the high school advanced orchestra in intensity (Table VIII), shows that half of this group scores above 83.25 in this test. These additional facts tend to indicate further that the capacity for intensity discrimination has been a factor in the selection of members of this high school advanced orchestra.

*Time.* The average of the beginning instrumental classes of 51.7 in the time test, as shown in Fig. 10, A, indicates that in this test, as in the intensity test, this average, so close to the mean of the percentile range, is of little or no significance as a determi-

nant for registration for special instruction in beginning instrumental classes. Reference to the distribution of this group in this test also shows that there is a comparatively even distribution throughout the range, tending to support the conclusion that time discrimination in terms of the least perceptible difference in the duration of time intervals used in this test was of little or no importance in the selection of the personnel of these beginning instrumental classes.

In considering the averages of the two junior high school orchestras, Fig. 10, A and B, it is noticed that there is a wide difference between the averages of the two groups in this capacity. The junior high school preparatory orchestra averages well below the mean of the percentile range while the junior high school advanced orchestra averages considerably above this mean. Considering the averages of these two groups, it seems reasonable to say, since one is above and the other below the mean of the percentile range, that evidently this capacity was of no significance in discouraging a continuation beyond the beginning instrumental classes; but since there is such a wide difference in the average of these two groups, this capacity must have been of influence in the distinction of higher and lower abilities in performance. With the high school advanced orchestra, capacity in this test must be of still greater importance, since the average is 69.5 as is shown in Table VIII.

However, this average of the high school advanced orchestra in time is the lowest of its six capacity tests which would indicate that it probably is not as important a selective factor as the other tests. But Table IV shows that more than one-third of the cases in this group rank in the tenth decile. Reference to Fig. 4, D, shows this concentration in the uppermost decile but also shows that there is not the sparseness of cases in the lower half of the range that is found in the distributions of this group in the other tests. It seems to indicate that those of very keen discrimination in this capacity have the best chances for selection to this organization, but that selection on the basis of this test is not as rigid as it is for the other tests.

*Consonance.* Fig. 11 represents the relative size of the aver-

ages of the four groups under discussion in the consonance test. The average of 54.4 may be considered as having slight importance as a selective factor for the beginning instrumental classes as it is only such a small difference from the mean of the percentile range. In considering the averages of the two junior high school orchestras in this respect, it seems that from the fact that the junior high school preparatory orchestra averages but slightly below the fiftieth percentile, and the junior high school advanced orchestra averages 14.9 above the mean of the percentile range, the averages combined would be high enough above the mean of the range to consider this more complex capacity of some influence in the selection of those who continue after the beginning instrumental course. In a comparison of the averages of these two groups themselves, it is quite evident that this capacity has been a factor in the assignment of the membership.

With the high average of 75.1, as shown in D of Fig. 11, it may be seen how the more complex capacity of consonance must have had its influence as a selective factor for the membership of the high school advanced orchestra. The negative skewness of D in Fig. 5, the fact that Table V shows that there is one-third of the cases in the tenth decile, and that Table VIII gives 77.5 as the median, are additional factors that tend to show that a higher capacity in consonance must have had a part in determining the personnel of this advanced instrumental group.

*Tonal Memory.* Fig. 12, shows the average for the beginning instrumental classes in tonal memory to be somewhat below the mean of the percentile range, as previously explained. It certainly can be said that this capacity was not a selective factor in determining a choice for special music instruction in the beginning instrumental classes. The relationship of the capacities of the two junior high school orchestras in tonal memory is comparable to that in time and warrants the same explanation. The wide difference between the average of the junior high school preparatory orchestra with its average of 39.1 and the average of the junior high school advanced orchestra with its average of 67.1 is surely indicative of this capacity acting as a discriminat-

ing force in these two groups of differing abilities. Such a large difference seems to show that this test is one of the most important as a means of making a distinction between the personnel of the advanced and preparatory orchestras. Considering the combined averages of these two groups, however, it seems that this capacity does not have significant influence in discouraging a continuation

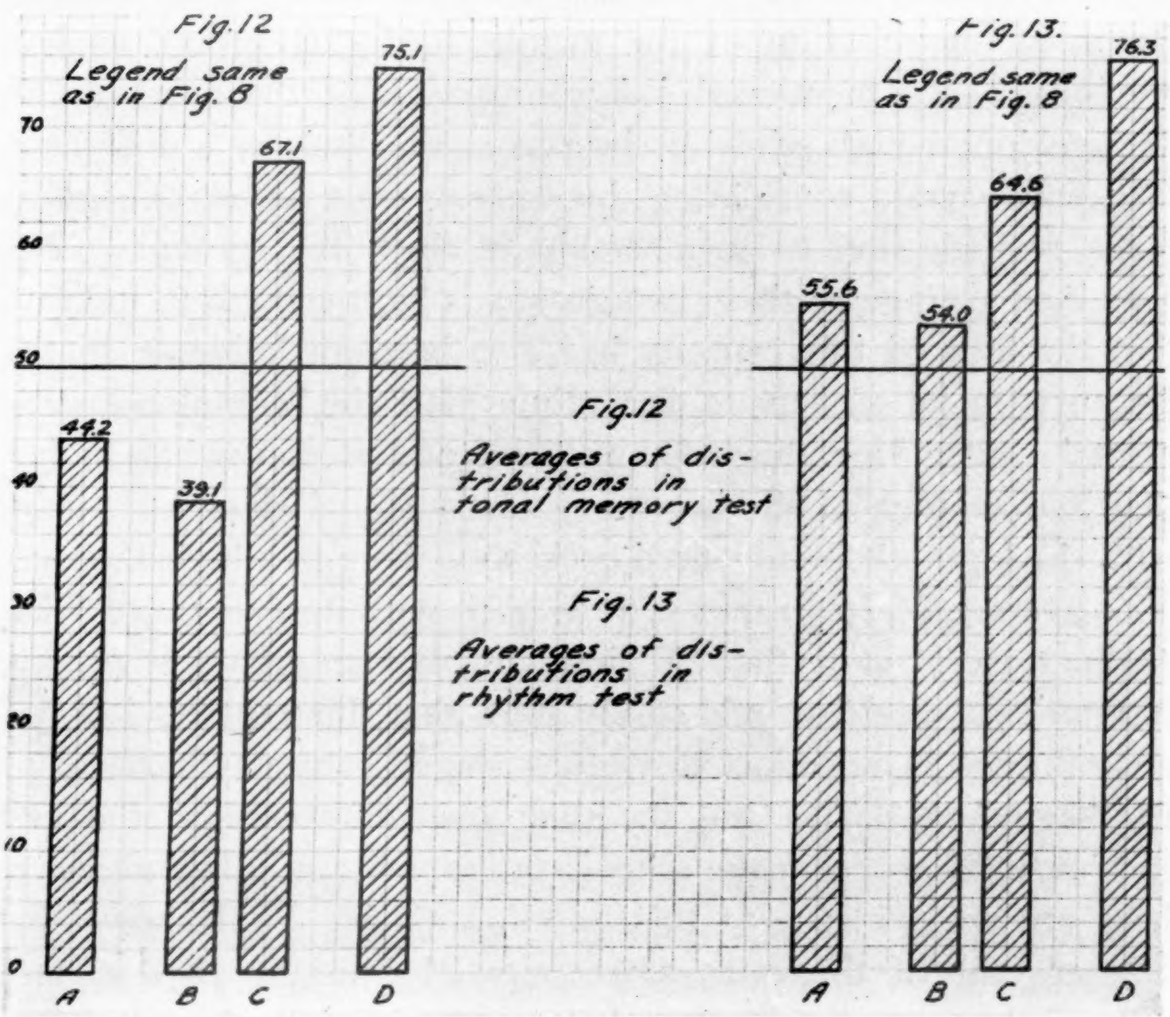



Fig. 12
Averages of distributions in tonal memory test

Fig. 13
Averages of distributions in rhythm test

of instrumental work after the completion of the beginning course.

The average of 75.1 in tonal memory for the high school advanced orchestra is one of the highest in the entire battery of tests and indicates that this test is one of considerable importance as a selective factor for this organization. By reference to the other measures of this distribution, shown in Table VIII, it is found that the median of 86.6 for tonal memory ranks a close second to pitch. Table VI shows that 70 per cent of the cases

are found in the three upper deciles. The results of these measures support the averages as an indication of the merits of this test in selection.

*Rhythm.* Examination of the averages of these four instrumental groups in rhythm, Fig. 13, shows variations in capacities of this test also. The average of the beginning instrumental class of 55.6, ranking next to pitch, can be considered as being a slight factor in the selection of the members of this group, as has previously been mentioned. A comparison of the averages of the two junior high school orchestras again discloses a difference that may warrant considering this capacity as a factor of significance for selection of membership in these two groups. The combined average of these two groups is high enough to indicate that the lack of this capacity has also been an influence in the discouragement of some to discontinue after the beginning instrumental course, for this combined average is somewhat higher than the average of the beginning instrumental classes. Again, with the high school advanced orchestra, there is a high average. This average of 76.3 ranks next to pitch with its average of 77.4. An increase of more than 20 above the average of the beginning instrumental classes would surely show that this capacity has had an influence in selection at various stages between the time of the beginning classes and the time for admittance to the best instrumental group in the school system. Again, other measures bear out the evidence of this selection. Table VIII shows that 50 per cent of the cases score over 81.2 in the rhythm test. Fig. 7 shows a distribution that is greatly skewed to the left. Table VII shows that only 7 cases out of 48 rank below the fiftieth percentile in the rhythm test. These measures tend to indicate that this test is one of the most important in selection at this high level of achievement.

*The effect of training.* The above interpretations rest upon the assumption that these measures are elemental in that they are not affected to any great extent by training. This conclusion rests upon experimental facts derived over a period of the last twenty-five years, the cumulative results of which have largely been responsible for furnishing us with a psychology of music. The

reports of *Seashore* (13) (14) (15), *Smith* (19), *Seashore* and *Mount* (17), *Klauer* (7), *Larson, D.* (9), *DeGraff* (3), *Seashore* and *Tan* (18), and others indicate that sensitiveness to these basic capacities is relatively elemental. Contradictory evidence as to the effect of training has not been offered.

Qualifying statements are sometimes made as to the validity of these tests in measuring elemental capacities, largely, it seems, because of the ineffectiveness of the responses obtained at the time of testing. A testing program instituted, however, at a point in a school system at which the children have previously had several years of both active and passive contacts with music and musical terms greatly eliminates these responsive difficulties. Of course in group testing, particularly at early ages, there are cases in which a single test does not always reach the physiological limit; it does not allow *E* to be sure that the cognitive limit approaches the physiological threshold equally well in every case. Each child in the group is given equal opportunity for preliminary practice within the limits of expediency for group testing; but internal evidence shows that sometimes a child through ignorance fails to grasp the technical factors involved even in these tests which are especially well built in simplicity of design. It is noticeable particularly in the tests of tonal memory and consonance in which the procedure seems to be somewhat more complicated for children.[8] This lack of cognition, however, is often associated with a limitation in innate capacity; for it places a talented individual of this type at a disadvantage in *O*'s interpretations in the preliminary test period. Training in music for these students probably would account for some small degree of improvement through the aid of a more technical grasp of the factors involved, but this influence on the averages would be slight as compared with the general increase at each level.

With the exception of these cases, the normal attentional and informational deficiencies are met by the use of different sets of norms,—eighth grade norms for junior high school students, and adult norms for the high school students. In fact, adult norms,

[8] Note the explanation of the concentration of cases in the lowest decile in tonal memory, p. 54.

especially for the tenth grade students, seem too high for the high school advanced orchestra. This would tend to reduce the influence of the special cases under consideration in this comparative study of averages.

While it is beyond the purpose of this study to attempt to substantiate or augment the results of experimentation on the effect of training, a number of incidental factors have been found in this study which are in accord with the established fundamental tenet in regard to training and which may well be mentioned in connection with this discussion.

In the previous treatment it has been noted that in each of the six tests there was an increase in the averages of the combined junior high school orchestras over those of the beginning instrumental classes in the junior high school with the exception of the one test, the sense of time, and in this capacity there was a great difference between the junior high school preparatory orchestra and the junior high school advanced orchestra. On the other hand the beginning classes tested about average in all the capacities. Previous to their entry into the beginning instrumental classes the children of these groups had gone through six years of intensive training in music. One capacity, the sense of pitch, may be taken as an example in order to show the opportunity for training in this specific capacity before registration for special instruction in instrumental music. In the lower elementary grades every child is given instruction in vocal music consisting of a large number of rote songs with subsidiary imitations in the matching of tones, *etc.*, for the purpose of giving training in the use of the voice, in ear-training, and for the elimination of the monotones. Following this the elementary grade pupil goes through a tonal and rhythmic training in the rote to note process which leads to sight-singing and finally to part-singing in the upper elementary grades. By the time these children reach the junior high school they have had six years of training and drill daily in vocal expression which calls for an exact ear-training in the fundamental capacities in question. Throughout this period of elementary training it is common observation that there are decided individual differences. But upon

their promotion to the junior high school no attempt is made to select the more talented pupils for the instrumental work, experimentally or otherwise. The result of the voluntary registration for the beginning instrumental classes, as we have seen, gives a group of students of only average talent such as might have been selected by chance.

The year's work, preparatory to entrance into one of the junior high school orchestras, was done under conditions that would reduce differences in training to a minimum. The instruction was given as regular class work in school time, one hour daily. In spite of this equal opportunity for training in this year's work, it was found that there was an increase in the average of those registering for orchestra work which follows as the second year course in instrumental music. As previously indicated, this increase in the averages may be attributed, not as a result of the training of the group as a whole during this one year, but to a natural process of selection of the better students through the elimination of the poorer students who have been discouraged and have not continued the work after a trial of varying lengths of time. It is unreasonable to attribute the increase in the averages to the year's training in instrumental music when the fact is considered that these children have had six years of music training previous to this first year of instrumental instruction. In fact, with the exception of the stringed instruments and one or two of the brass instruments, there is not the rigid demand for innate talent that there is in expression by means of the human voice, for in many instruments, considering pitch for example, the construction of the instrument takes care of part of the requirements imposed on the voice in singing. Also, a differentiation in the demands of the specialized parts that are played by the various instruments would seem to require less talent from some instruments than from the voice. Aside from the requirements of talent, the fact that the mechanical requirements of the instrument demands a part of the effort of the first year's instrumental training must also be considered.

In the light of these facts, it may be said that the demands of the first year instrumental instruction on the natural talent of the

child are no greater, and for some instruments probably less, than for the instruction in vocal music of the preceding six years in the elementary grades. It is, therefore, unreasonable to attribute an increase in the averages of the junior high school orchestras over that of the beginning instrumental classes to the one year's training in the beginning classes, but rather to the natural elimination of those less talented who have discontinued the work because the demands of the instrument were such that it was discouraging for them to continue this special instruction due to a limitation of their natural aptitudes for the work. This is the theory maintained throughout the study. The more advanced the instrumental work becomes, the more exacting are the demands on the student's talents. There is a natural limit beyond which the pupil is handicapped in his effort to achieve. His performance is affected and he either becomes discouraged and discontinues through his own volition or he is eliminated in competition with better performers.

In addition to this difference in the averages of the tests between the beginning classes and the combined junior high school orchestras as a whole, the differences in the averages of the tests between the two orchestras themselves should be considered and their significance noted. Under a routine of a daily one-hour class in school time for the training of the beginning instrumental students for the orchestra work the year following, it is of special significance that the group which is selected for the advanced orchestra as the better players should average so much higher in the tests than those who made up the group of poorer players. With the daily one-hour practice for the beginning classes in school time under the same instructor, there are conditions for training which would compare very favorably with those necessary for a controlled experiment devoted to a training problem. So when there is a difference in the averages of two groups, as is found in this case in pitch, time, consonance, tonal memory, and rhythm under such training conditions it may be said that the evidence points to attributing the higher averages of the advanced group to talent rather than to training.

Another factor of significance may be found in an observation of the organization of the high school advanced orchestra. A plurality of the members of this orchestra were in their first year in high school. This, of course, shows that these students went directly from the junior high school orchestra to the high school advanced orchestra without having preliminary training in one of the high school preparatory orchestras. Since the high school advanced orchestra ranks much higher in the measures of talent than any other group, the evidence points towards a requisite of talent for membership rather than the length of time in training.

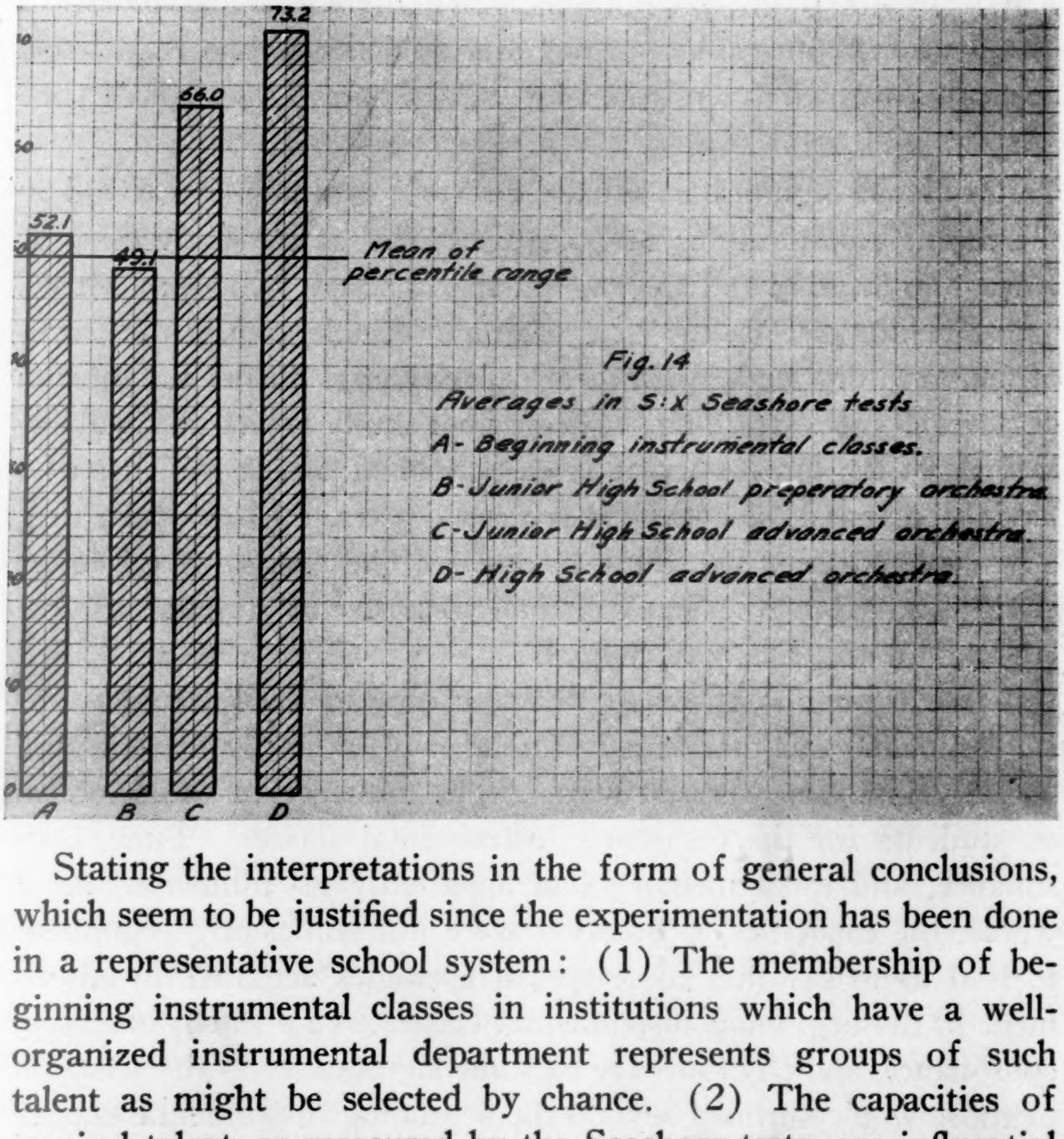
Results of significance on the effect of training are found in the recent investigations of *Larson, R. C.,*[9] at the University of Iowa, and *Stanton* and *Koerth*[10] at the Eastman School of Music. These results disclose the lack of an appreciable gain in the scores of conservatory students in these capacity tests during the interim of several years' training. The former study treats all available records of the University of Iowa School of Music students who have been tested over various spans of years, during which they have had continuous training in music. The results of the latter study are from the experimental records of regular course students at the Eastman School.

*Summary and conclusions.* In returning to the interpretations the following summary may be made: (1) Pitch, rhythm, and possibly intensity were of some slight influence in the selection of students for the beginning instrumental classes. Time, consonance, and tonal memory had apparently no influence. As a whole, the capacities in question were not sufficiently prominent to lead us to say that these special aptitudes actuated an enrollment in the beginning instrumental classes. (2) Pitch, intensity, consonance, and rhythm were of some significance in the selection of those who continued beyond the beginning instrumental classes into the junior high school orchestras. (3) All of the capacities

[9] Studies on the Seashore Measures of Musical Talent (in preparation).

[10] Validation of Seashore Measures of Musical Talent after an interim of musical training (in M.S.).

measurable by the tests with the exception of intensity were of influence in a differentiation of students for the junior high school advanced orchestra and the junior high school preparatory orchestra. (4) All of the capacities as measured by the six Seashore Measures of Musical Talent were of still greater significance in the selection of the membership of the high school advanced orchestra.




Stating the interpretations in the form of general conclusions, which seem to be justified since the experimentation has been done in a representative school system: (1) The membership of beginning instrumental classes in institutions which have a well-organized instrumental department represents groups of such talent as might be selected by chance. (2) The capacities of musical talent, as measured by the Seashore tests, are influential in the selection of the personnel of the more advanced groups. At each higher stage this influence is increasingly significant. This conclusion forms a basis for the discussion of the problem of prediction in the following section.

## IV. The Problem of Prediction

The results of the present investigation show that there is a tendency for an increasing negative skewness in the distributions of scores on the Seashore tests at higher levels of achievement. This skewness varies from quite even distributions in the tests of the beginning instrumental groups to a large negative skewness in the distributions of the advanced groups. Also measures of central tendency increase at these higher levels of ability. This indicates a selection represented by a long process of trial and error. As has been pointed out, the trial and error method is expensive.

Since the results of the present investigation tend to show that, under existing methods of organization in instrumental music, the beginning classes represent a chance selection; and since they tend to show further that the capacities of musical talent have functioned in the trial method of selection at each higher level of achievement, why not determine the rating of the prospective instrumental student before training begins and predict his success in terms of the measured capacities of the more advanced groups of which he hopes to become a member? Furthermore, why not employ these tests in a survey of the entire school population in order that talent may be recognized, classified, and trained? This would represent an approach to the solution of the various problems accruing to the present volunteer and trial method of selection.

The supervisor or instructor of instrumental music should have at hand group distributions of capacity tests of the more advanced musical organizations in the school system. A student contemplating instrumental instruction could be given the tests and the position of his scores could be located on the distributions. His chances for success could be judged by the relative position of his scores on these distributions.

Of course, it is recognized that the Seashore Measures of Musical Talent do not account for all the capacities making up talent in music. *Seashore* states (12, p. 4) that "These six measures do not constitute a complete survey of musical talent, . . . but they are specific measures of these six basic capacities.

They do not measure the musical mind as a whole, but they do measure specific and fundamental traits of the musical mind." The classification of the factors of the musical mind in *Seashore's* text (14, pp. 7–8) shows that these six tests do not include all of the sensory capacities, nor do they take into consideration the motor capacities, which condition the musical response. At present, motor tests are not practical for general group testing. They require a large amount of laboratory apparatus, and a great amount of time is necessary for the individual testing. Also the measurement of musical feeling is not considered since suitable tests for measuring the affective response to music are not available. Such variables as interest, health, attitude of family towards music, influence of outside activities (interests are too many and too varied), organization of personal schedule, private lessons, relations with instructors, disposition, I.Q., and the quality of the instrument owned also have their effect.

But in spite of the many variables it has been found that these six basic capacities, as measured by the Seashore tests, are significant factors and do influence the selection of the membership of groups at higher levels of achievement. Therefore these capacities should be recognized through a testing program for guidance before training begins.

Suggestive of such a possibility in the selection and guidance of talent is the following plan. Table IX presents the quartile

TABLE IX. *Quartile measures for prediction*

| | $Q_1$ | $Q_2$(M) | $Q_3$ |
|---|---|---|---|
| Pitch | 62.4 | 87.0 | 94.2 |
| Intensity | 52.8 | 83.3 | 93.2 |
| Time | 42.8 | 69.5 | 92.4 |
| Consonance | 49.6 | 77.5 | 92.0 |
| Tonal Memory | 62.0 | 86.6 | 92.6 |
| Rhythm | 62.8 | 81.2 | 92.8 |

measures of the various distributions of percentile scores made by the high school advanced orchestra in all six tests. A score of 94 in pitch is found on the distribution at $Q_3$. Only six out of 100 of the general population can score so high in this capacity. But in the orchestra we find one out of four with a score at this point or higher. In other words, approximately

only one out of sixteen from the general population can qualify with such a keen pitch discrimination but in this high school advanced orchestra one of every four ranks in this upper quartile.

Similarly, at another point on the distribution,—at $Q_2$, the median, although only 13 per cent, or about 1 out of 8 of the general population has a pitch discrimination equal to this, or 50 per cent of the members of the orchestra qualify at this level.

The significance of this for purposes of prediction may be illustrated by taking an example at $Q_1$. A prospective student with a score at the 62 percentile may be given the following explanation. A score of 62 is considerably above an average score. But its position on the distribution of the high school advanced orchestra is at $Q_1$. Three-fourths of the members of the orchestra score above that point. From a comparison of the relative position on the distribution, along with a comparison of the relative positions of the scores in the other tests and other information available, it may be decided whether the chances are favorable enough to warrant a special course of instrumental instruction which aims for a proficiency necessary for the organization to which the student aspires and in terms of which his talents are compared.

In this connection, a plan is necessary for a weighting of the tests. It is conceded that the tests are not all equal in importance, the sense of pitch usually being considered as the most valuable. But associated with this problem of weighting the tests in a general way is the problem of the weighting of the tests for the various instruments. Even more than that, we must consider the problem of weighting the tests according to the way in which the performer wishes to use the instrument. Is the student naturally adapted to play the violin or the piano? Does he expect to be a soloist, accompanist, or a member of an ensemble? How proficient does he expect to become in one of these lines? Such are the problems facing the music-psychologist in his attempt to weight the tests for purposes of prediction.

It has only been the purpose of this study to examine a cross-section of an instrumental music department, trying to determine the capacity of talents at the different levels and from this to

point out the possibility and necessity for the scientific selection of talent for the special instruction in instrumental music. Along with this it has only been possible to suggest some of the many diverse problems for research associated with this basic study. Experimentation is now under way in a public school system for the purpose of investigating the practical application of these aptitude tests as a selective agency. We hope that results may be obtained that will be basic not only for the classification of students in instrumental music, but will differentiate talents for other aspects of school music as well.

In addition, we might mention that an avocational guidance program will likely have an accompanying influence on an educational guidance program in school music, necessitating a special line of research from this angle.

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# A STUDY IN THE SEASHORE MOTOR-RHYTHM TEST

BY

J. T. NIELSEN

*Introduction; apparatus; observers; procedure; results; conclusions; bibliography.*

*Introduction.* The purpose of this study was two-fold: (1) to study training in rhythmic performance, and (2) to improve and further standardize a measure of rhythmic auditory-motor co-ordination which can be used as one of a series of tests in the prediction of success and ability in musical performance.[1]

*Apparatus.* The apparatus used in this experiment was the *Seashore* phonographic chronograph as adapted by *Seashore, R. H.* (22). The latent time of the telephone receiver was found to be negligible, and the latent time of the pen magnet to the crest was .013 sec. In the experiment this was corrected by setting the pattern one-hundredth of a second forward. Two brads placed to correspond with the contact points enabled *E* to adjust the paper to this desired position. Following the suggestion of *Ream* (16) and *Seashore* (22), the telegraph key with a resistance of 100 g., with amplitude of 3 mm., was used in this experiment. The key had silver contact points which were cleaned after every third trial.

The regularity of the phonograph motor was tested by the use of an adaptation of *Seashore's* (21) stroboscopic method of reading vibrational frequencies. An electrically driven tuning fork of 50 d.v. was attached to a telephone transmitter which was connected to a neon lamp. A stroboscopic disc containing 50 dots was placed on the phonograph and a record used as a dark background so that the dots would be more perceptible. In order to

[1] The research of SEASHORE, R. H. (22), has furnished the basis for this study and has been invaluable to the writer in proceeding with the problem. I wish gratefully to acknowledge my indebtedness to Dean C. E. Seashore, who directed this study, and also to express my appreciation to Miss Grace Watkins for her kind assistance in giving the motor rhythm tests.

facilitate the testing of the apparatus for the entire length of its run a metronome was set at the rate of one beat per second. The reading was then made by counting the dots that moved past a specific mark during one stroke of the pendulum. This testing was done with the motor running at the rate of 60 r.p.m., as this speed was the rate adopted for our experiment. A speed of 60 r.p.m. is more reliable than lower speeds for phonograph motors. During the entire span from the fiftieth revolution to the three-hundredth the apparatus was found to be very reliable, not only in considering the span as a whole, but also from one revolution to the next.

In order to facilitate the reading of the graphic record a new method of scoring was devised. In *Seashore's* (22) study, sixteen one hundredth second lines were stamped upon each of the four parts of the record, and the taps were counted in each hundredth second interval. Then an assumed mean was taken and the variability in the score from this mean was measured in terms of standard deviations. This scoring could not be done very quickly and an improvement in this procedure was attempted. Twenty-five individual case records were taken from the original data of *Seashore, R. H.*(22), and all four parts of each record were scored in terms of standard deviations. The amount of correlation between these readings was then determined. Each part was correlated with the other three parts and this resulted in six correlations. These ranged from .75, p.e. .01, to .92, p.e. .01. The correlations prove that it is not necessary to read the entire record, because the score on one pattern correlates highly with the score on the other three.

In order further to facilitate the reading of the graphic record a different pattern was designed and was printed upon the paper discs. Previous experimentation established the fact that individual deviations from the mean or standard ranges within a plus or minus nine-hundredths of a second. Consequently this range was adopted as that of the reading scale. This range was then divided into five intervals, five steps being selected so as to make reading easier and yet secure a good distribution of scores. The first interval represents one-hundredth of a second and the

remaining four intervals following Weber's law are in logarithmic ratio to the first interval. This ratio was found to be as follows:

| Interval | Hundredths of a second |
|---|---|
| 1 | 1. |
| 2 | 1.30 |
| 3 | 1.68 |
| 4 | 2.19 |
| 5 | 2.83 |
| Total | 9. |

The common multiple is 1.29.

The score was computed by the use of a weighted average. A tap in interval No. 1 was given the value of one, a tap in interval No. 2 the value of two, and the other intervals are weighted in the same manner, the number of the interval corresponding to the value given that space. The taps in each interval are then counted and given their respective values. In this experiment the test was divided into six parts with ten taps in each part, making 60 in all, and the average of the six divisions was determined. The total score could be used but it was considered too large for convenient use and the finding of the average took but a few minutes. The mean or standard in Fig. 1 corresponds exactly with the stimulus sound. The numbers on the outer edge of the circle represent the interval and its value when weighted for scoring.

*Observers.* Twenty students were taken at random and twenty were selected from the School of Music. The students from the School of Music were selected by an instructor in that department as being ten good and ten poor students in rhythmic playing, their ability being so determined by their instrumental work. These students were trained for ten consecutive days, a half hour given to practice on each day. The training was motivated by introducing self rivalry and also group competition. The *O*s were shown after each section during the practice period where they had erred by anticipating or delaying their tapping. Six tests lasting ten seconds each were taken during this period, followed by practice and rest. Throughout the series the *O*s were urged to continue the improving of their score.

*Procedure.* *O* was seated in a chair with the telegraph key directly in front of him and the following instructions were given: "Lean forward toward the key in a position of bodily tension. Hold the receiver to your ear with your left hand and grasp the key between the thumb and the middle finger with the index finger on top of the key. The wrist and forearm should not

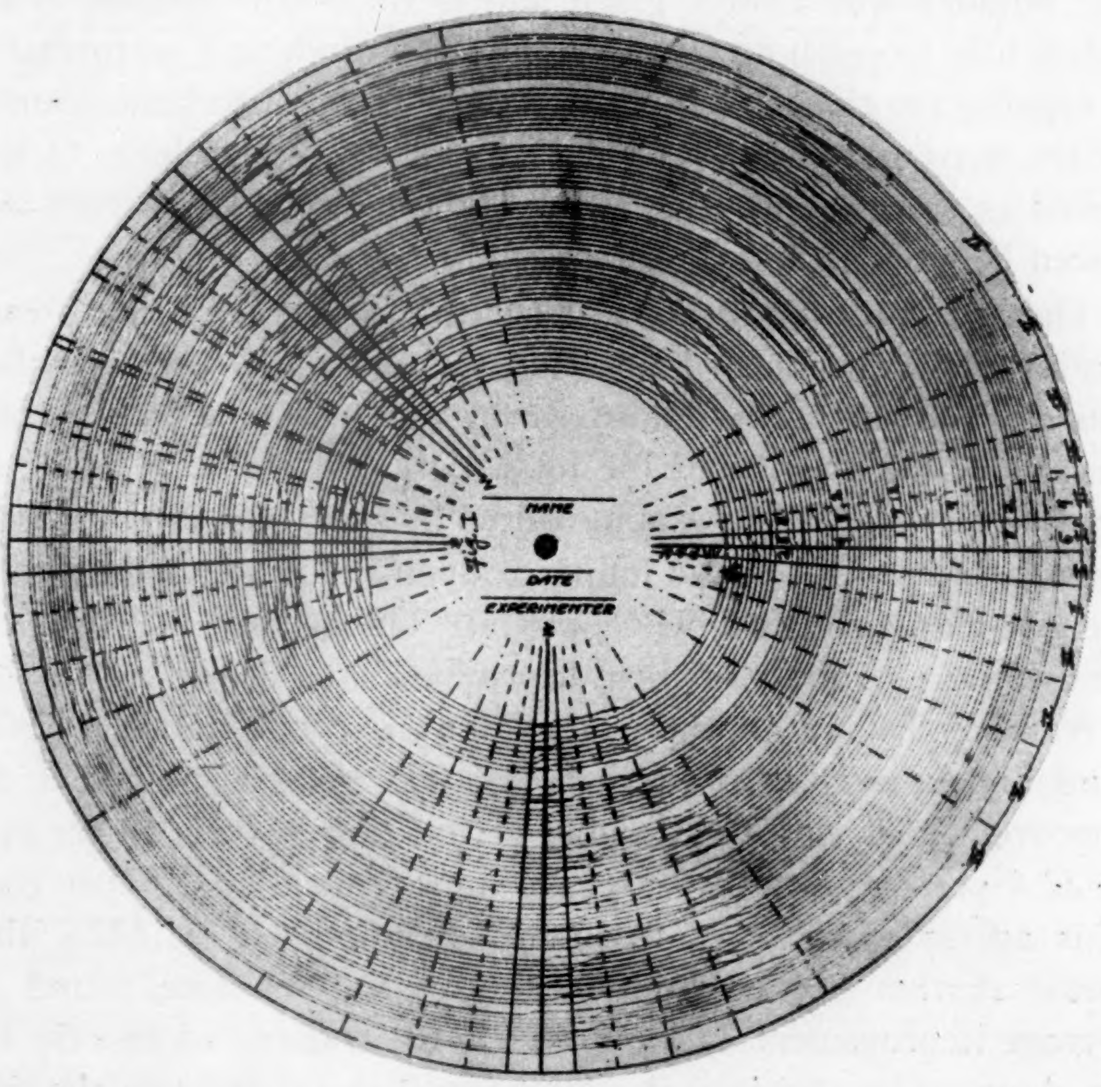


FIG. 1

rest upon the table. If *O* was left-handed, the right hand held the receiver. If *O* was entirely unable to tap in this manner, he was allowed to tap in some similar way with as little movement as possible. The motor was then started and these additional instructions were given: "It is your task to keep in time with the rhythmic pattern which you hear in the receiver with the highest precision possible so that the click of the key shall coincide exactly with every click in the telephone receiver. Attend to the

sound in the receiver and make the tapping of the key become automatic."

If *O* failed to grasp the rhythm or was unable to tap the pattern, *E* helped him by tapping the rhythm with *O*'s hand on the key. The rhythm was then grasped sufficiently to enable *O* at least to follow the pattern. A preliminary practice of four or five minutes was always given and is important because it requires time to reach maximally attentive attitude and performance in tapping the rhythm. In order to avoid any disturbance caused by the movements of *E* and the running of the machine, *O* was seated as far away as possible from the motor and a screen was placed between *O* and the apparatus.

The arithmetic mean was determined for the six tests in each day's trial. The standard deviation for each daily score was then found. The amount of improvement was measured by the comparison of the average of the total score and the score made on the first day. The gain was measured by the average of the total score to avoid any erratic influence upon the score, and to show the true gain during the whole period. The average improvement of the entire group was then determined.

*Results.* Table I gives the tabulation of scores, standard deviations and improvement of each *O*. The results show that the improvement during the training period ranges from .7 per cent to 22.4 per cent, with an average improvement of 7.8 per cent. This agrees with the statement of *Seashore, R. H.*(**22**), that motor rhythm can be slightly improved. Seashore found an average improvement of 5 per cent in the training of five *O*s for six days. The standard deviations in Table I indicate the fact that there is little variation in the individual's ability to tap the rhythm and the amount of variation is fairly uniform for the 40 *O*s.

An analysis of the curve in Chart I shows that the greatest improvement came on the first day, with some improvement on the next three days. After the fourth day there was but little fluctuation in the score. This indicates that the limit of ability to tap the rhythm was reached after little practice and in considering the group as a whole this limit was maintained throughout

TABLE I. *Table of score for ten days' practice*

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O | A. | S. D. | A. | S. D. | A. | S. D. | A. | S. D. | A. | S. D. | A. | S. D. | A. | S. D. | A. | S. D. | A. | S. D. | A. | S. D. | A. A. | Med. | % Imp. |
| 1 | 19.0 | .8 | 18.0 | 1.1 | 17.7 | 1.2 | 17.5 | .9 | 17.7 | 1.2 | 17.7 | 1.2 | 17.7 | 1.2 | 17.7 | 1.1 | 17.7 | 1.4 | 17.8 | 1.4 | 17.9 | 17.7 | 7.7 |
| 2 | 26.5 | 7.8 | 23.3 | 3.8 | 26.5 | 5.3 | 22.8 | 3.4 | 25.8 | 3.5 | 19.7 | 2.8 | 17.7 | 3.7 | 22.8 | 7.5 | 21.2 | 2.7 | 22.5 | 3.8 | 22.9 | 22.8 | 8.3 |
| 3 | 15.5 | 1.8 | 13.3 | 1.6 | 14.2 | 1.4 | 15.7 | 2.6 | 13.7 | 2.0 | 14.8 | 1.9 | 15.8 | 1.3 | 14.2 | 2.2 | 13.2 | 1.3 | 13.5 | 1.7 | 14.4 | 14.2 | 9.5 |
| 4 | 18.7 | 2.6 | 16.3 | 2.2 | 15.0 | 3.3 | 14.7 | 2.4 | 17.7 | 4.0 | 14.5 | 2.1 | 14.5 | 1.4 | 14.7 | 2.7 | 14.8 | 1.8 | 15.3 | 1.2 | 15.6 | 14.9 | 16.6 |
| 5 | 19.7 | 2.4 | 19.8 | .8 | 14.5 | 1.8 | 16.0 | 2.8 | 15.8 | 2.1 | 15.5 | 3.6 | 15.8 | 2.0 | 16.8 | 2.1 | 15.8 | 2.0 | 17.2 | 1.7 | 16.7 | 15.9 | 15.1 |
| 6 | 22.5 | 2.9 | 23.0 | 3.9 | 20.3 | 2.2 | 19.8 | 1.3 | 18.2 | 1.2 | 18.0 | 1.1 | 18.0 | 1.6 | 18.0 | 1.6 | 18.5 | 1.6 | 18.2 | 1.6 | 19.4 | 18.4 | 13.3 |
| 7 | 45.8 | 3.1 | 45.7 | 1.9 | 45.3 | 2.6 | 45.0 | 2.4 | 45.5 | 2.4 | 44.7 | 2.7 | 44.2 | 3.5 | 46.2 | 2.9 | 46.8 | 2.0 | 45.8 | 3.1 | 45.5 | 45.6 | .7 |
| 8 | 26.2 | 1.4 | 23.5 | 2.1 | 23.2 | 3.1 | 23.2 | 2.7 | 23.2 | 2.1 | 23.7 | 1.8 | 23.2 | 3.2 | 23.3 | 2.7 | 24.0 | 3.2 | 24.2 | 1.9 | 23.8 | 23.4 | 9.2 |
| 9 | 30.8 | 4.0 | 29.7 | 5.1 | 29.8 | 3.8 | 29.7 | 4.4 | 30.5 | 4.1 | 29.5 | 4.7 | 32.2 | 3.3 | 29.0 | 5.0 | 30.0 | 3.0 | 29.2 | 3.7 | 30.1 | 29.8 | 2.2 |
| 10 | 23.8 | 4.2 | 24.0 | 2.3 | 29.0 | 2.7 | 25.7 | 7.5 | 19.0 | 5.0 | 17.8 | 3.4 | 20.2 | 2.8 | 16.5 | 2.2 | 16.8 | 2.8 | 17.0 | 1.6 | 21.0 | 19.6 | 7.7 |
| 11 | 21.0 | 1.8 | 20.0 | 3.5 | 20.2 | 2.0 | 19.2 | 1.6 | 19.3 | 1.7 | 20.2 | 2.2 | 20.2 | 3.1 | 22.0 | 3.9 | 21.2 | 3.9 | 19.8 | 2.0 | 20.3 | 20.5 | 3.5 |
| 12 | 19.0 | 2.5 | 17.0 | 2.0 | 14.5 | 1.7 | 15.5 | 1.2 | 15.8 | 1.6 | 15.0 | 1.7 | 15.7 | 1.6 | 15.2 | 1.0 | 15.3 | 2.0 | 16.3 | 1.2 | 15.8 | 15.4 | 16.7 |
| 13 | 15.8 | 1.4 | 17.5 | 1.9 | 16.2 | 1.8 | 15.2 | 1.7 | 14.8 | 1.1 | 14.5 | 1.0 | 15.2 | 1.6 | 15.3 | 1.9 | 14.5 | 1.9 | 14.2 | 1.4 | 15.3 | 15.3 | 3.2 |
| 14 | 25.2 | 1.8 | 22.5 | 2.0 | 23.2 | 2.3 | 23.2 | 2.3 | 22.2 | 1.7 | 22.0 | 1.8 | 21.8 | 1.7 | 22.2 | 1.4 | 22.5 | 2.5 | 22.3 | 1.0 | 22.8 | 22.4 | 9.7 |
| 15 | 24.3 | 1.4 | 24.5 | 1.6 | 23.5 | 2.4 | 23.8 | 1.8 | 23.0 | 2.1 | 23.5 | 2.0 | 23.8 | 1.9 | 23.8 | 1.5 | 22.8 | 2.4 | 23.8 | 1.9 | 23.7 | 24.0 | 3.0 |
| 16 | 17.8 | 2.3 | 17.5 | 2.0 | 16.8 | 2.7 | 17.3 | 2.4 | 17.3 | 1.9 | 17.2 | 2.4 | 17.7 | 2.0 | 17.5 | 1.3 | 17.3 | 1.6 | 17.5 | 1.4 | 17.4 | 17.6 | 2.9 |
| 17 | 37.7 | 4.3 | 34.2 | 3.7 | 34.7 | 3.6 | 35.5 | 5.4 | 34.3 | 4.0 | 33.2 | 3.2 | 33.8 | 3.9 | 32.5 | 5.9 | 34.2 | 3.7 | 33.7 | 3.6 | 34.4 | 34.2 | 8.8 |
| 18 | 28.7 | 2.5 | 29.3 | 2.6 | 27.8 | 2.0 | 28.3 | 2.5 | 26.3 | 2.9 | 26.5 | 1.5 | 25.7 | 2.9 | 25.8 | 2.3 | 25.8 | 1.8 | 26.0 | 1.9 | 27.0 | 26.4 | 5.7 |
| 19 | 23.0 | 1.8 | 21.5 | 3.0 | 20.5 | 2.2 | 22.2 | 2.0 | 22.2 | 3.4 | 22.0 | 1.9 | 22.8 | 2.1 | 22.8 | 3.2 | 24.3 | 2.6 | 22.2 | 2.2 | 22.4 | 22.6 | 2.9 |
| 20 | 47.8 | 4.6 | 44.2 | 2.8 | 43.3 | 2.9 | 43.0 | 2.6 | 45.0 | 3.7 | 45.8 | 3.0 | 45.8 | 3.7 | 46.0 | 3.2 | 45.8 | 2.8 | 45.7 | 2.5 | 45.2 | 45.8 | 6.9 |
| 21 | 17.7 | 2.3 | 16.3 | 2.0 | 17.3 | 2.0 | 16.2 | 1.9 | 13.2 | 1.2 | 13.3 | 1.0 | 13.8 | 1.8 | 13.8 | 1.7 | 14.0 | 1.9 | 13.8 | 1.8 | 14.9 | 13.9 | 14.4 |
| 22 | 48.2 | 4.1 | 46.3 | 3.0 | 45.2 | 2.6 | 47.3 | 2.4 | 46.2 | 2.4 | 46.7 | 2.7 | 46.2 | 2.9 | 47.3 | 3.5 | 38.0 | 3.6 | 46.2 | 2.1 | 46.8 | 46.5 | 2.9 |
| 23 | 38.3 | 4.9 | 34.2 | 2.8 | 35.2 | 3.0 | 35.0 | 3.7 | 34.8 | 3.5 | 38.0 | 5.6 | 35.3 | 3.0 | 34.7 | 2.5 | 35.8 | 2.6 | 36.0 | 3.1 | 35.7 | 35.3 | 7.9 |
| 24 | 24.2 | 3.5 | 23.2 | 3.9 | 19.2 | 1.5 | 17.0 | 1.0 | 20.2 | 2.1 | 18.3 | 1.4 | 17.8 | 1.5 | 18.3 | 2.4 | 19.0 | 3.1 | 18.5 | 2.2 | 19.6 | 18.8 | 18.2 |
| 25 | 22.2 | 3.4 | 16.7 | 1.9 | 15.5 | 1.5 | 16.7 | 2.0 | 16.0 | 2.0 | 15.3 | 1.4 | 18.0 | 1.8 | 15.7 | 1.8 | 16.0 | 1.9 | 15.7 | 1.3 | 16.8 | 16.0 | 22.4 |
| 26 | 18.0 | 1.0 | 18.2 | 1.4 | 18.7 | 1.1 | 18.0 | 1.3 | 17.8 | 1.4 | 17.0 | 1.2 | 17.8 | 1.5 | 17.7 | 1.1 | 18.0 | 1.2 | 17.2 | 1.5 | 17.8 | 17.9 | .9 |
| 27 | 18.7 | 2.4 | 19.8 | 2.4 | 18.8 | 2.3 | 16.2 | 1.4 | 17.5 | 2.1 | 17.3 | 2.0 | 17.8 | 2.0 | 16.5 | 1.9 | 17.8 | 1.6 | 17.8 | 1.6 | 17.8 | 18.1 | 4.4 |
| 28 | 37.8 | 4.1 | 34.7 | 3.8 | 36.5 | 4.2 | 35.8 | 3.0 | 35.7 | 3.7 | 34.8 | 3.8 | 35.3 | 3.8 | 34.8 | 3.8 | 35.0 | 3.6 | 34.8 | 3.8 | 35.5 | 35.2 | 6.2 |
| 29 | 29.2 | 2.6 | 27.7 | 2.7 | 27.2 | 2.9 | 28.3 | 3.5 | 26.8 | 2.0 | 27.2 | 2.1 | 27.2 | 2.9 | 27.2 | 1.2 | 26.2 | 1.3 | 26.5 | 2.1 | 27.3 | 27.2 | 4.9 |
| 30 | 31.8 | 3.9 | 30.2 | 3.3 | 29.0 | 3.7 | 30.7 | 3.5 | 29.2 | 3.7 | 28.8 | 2.4 | 28.8 | 2.1 | 28.2 | 2.9 | 29.5 | 3.0 | 28.7 | 2.4 | 29.5 | 29.4 | 3.7 |
| 31 | 18.2 | 2.2 | 21.8 | 3.0 | 16.0 | 1.0 | 15.2 | .9 | 15.3 | .9 | 14.7 | 1.2 | 14.7 | 1.3 | 14.8 | 1.9 | 14.7 | 1.2 | 14.7 | .9 | 16.0 | 15.0 | 16.6 |
| 32 | 17.8 | 2.2 | 15.7 | 1.1 | 15.7 | 1.3 | 15.8 | 1.6 | 16.2 | 1.7 | 14.2 | 1.9 | 16.3 | 1.3 | 15.7 | 1.0 | 15.8 | 1.5 | 16.0 | 1.1 | 16.1 | 16.0 | 4.9 |
| 33 | 20.7 | 2.2 | 16.8 | 3.3 | 16.2 | 1.7 | 15.8 | 2.0 | 18.7 | 2.6 | 17.3 | 1.4 | 19.2 | 1.9 | 17.2 | 1.7 | 17.3 | 2.0 | 17.2 | 1.7 | 17.6 | 17.3 | 11.0 |
| 34 | 27.3 | 1.9 | 24.3 | 1.3 | 24.0 | 1.5 | 23.8 | 1.5 | 23.8 | 1.3 | 24.0 | 2.1 | 24.5 | 2.1 | 23.8 | 1.0 | 24.2 | 1.2 | 24.2 | 1.1 | 24.4 | 24.1 | 9.4 |
| 35 | 36.2 | 5.3 | 34.7 | 4.2 | 31.3 | 7.7 | 37.2 | 4.9 | 33.0 | 3.9 | 33.2 | 3.1 | 33.2 | 3.1 | 32.8 | 3.8 | 34.8 | 3.6 | 34.2 | 4.7 | 35.1 | 34.5 | 4.6 |
| 36 | 18.7 | 1.1 | 15.3 | 1.8 | 15.3 | 1.2 | 15.0 | .8 | 15.3 | 1.3 | 15.0 | 2.2 | 15.0 | 2.1 | 14.3 | 1.5 | 14.8 | 1.1 | 15.0 | 1.0 | 15.4 | 15.2 | 12.6 |
| 37 | 18.8 | 1.3 | 17.8 | 1.0 | 15.8 | .6 | 17.7 | 1.5 | 17.8 | 1.3 | 18.2 | 1.8 | 17.7 | 1.1 | 17.8 | 1.0 | 17.0 | 1.1 | 17.5 | .9 | 17.7 | 17.8 | 3.9 |
| 38 | 27.2 | 2.6 | 25.5 | 2.6 | 25.8 | 2.7 | 25.0 | 1.9 | 26.2 | 2.6 | 26.5 | 2.6 | 25.4 | 1.7 | 25.8 | 2.1 | 25.7 | 1.6 | 25.8 | 1.8 | 25.9 | 25.9 | 7.7 |
| 39 | 34.2 | 2.9 | 27.3 | 7.3 | 32.5 | 5.9 | 35.3 | 6.7 | 33.3 | 5.7 | 34.7 | 4.7 | 33.3 | 5.8 | 33.2 | 3.7 | 32.8 | 3.6 | 32.7 | 3.9 | 33.3 | 33.0 | 3.9 |
| 40 | 16.8 | 2.1 | 15.5 | 1.1 | 18.5 | 3.2 | 15.7 | 1.0 | 15.2 | 1.1 | 15.7 | 1.8 | 15.2 | 1.1 | 15.3 | .9 | 15.3 | .9 | 15.3 | 1.2 | 15.9 | 15.4 | 4.7 |
| | | | | | | | | | | | | | | | | | | | Average Improvement | | | | 7.8 |

LEGEND TO TABLE I

A.—Average of the six tests during one day's practice.
S. D.—Standard deviation.
A. A.—Average of the averages.
Med.—Median.
% Imp.—Per cent improvement.
Numbers above refer to practice periods.

the entire period. The minor fluctuations in the curve and also in the daily score are due to the difficulty in maintaining the level reached during practice. These results are in harmony with the assertion of *Thorndike* (27) that any function can be improved, and that in narrow sensory-motor functions the amount of improvement is small and the limit is reached early in the training period.

Chart II shows the effect of *O*'s improvement on the percentile rank. The amount of increase in percentile rank ranges

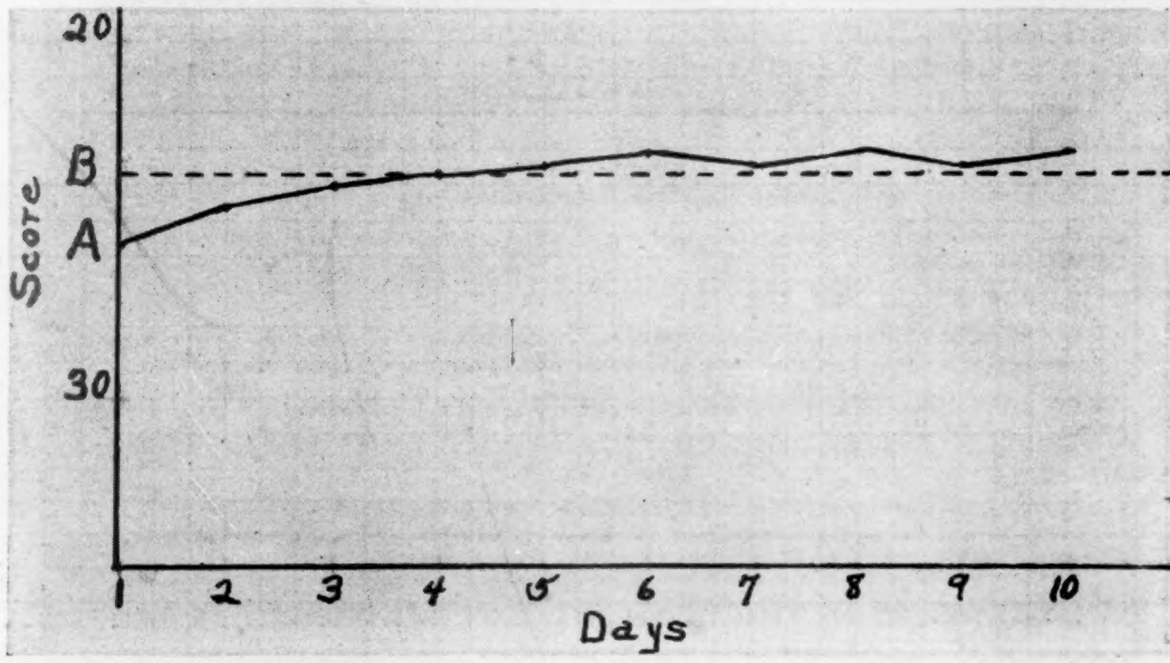


CHART I

from zero to 23 per cent, with an average increase of 5 per cent. Thus the percentile rank of the majority of the *O*s was little affected by the improvement during the practice period. A change of five in percentile rank would not have any significant effect upon the rating of the individual's ability in rhythm. Thus the results indicate a good distribution of scores and little improvement in the function.

In order to determine the relation between individual score and improvement a correlation of the scores and percentage improvement was made for the entire 40 *O*s. The coefficient of correlation was found to be .08 p.e. .14. Thus there is no significant relation between ability to tap the rhythm and the amount of improvement. The average improvement of the 20 *O*s from the

School of Music and of the 20 students selected at random was determined in order to compare the amount or percentage of improvement of the two groups. The percentage increase in score of the music students was found to be 8.15, while the improvement of the unselected group was 7.45 per cent. This indicates that there is no significant relation between musical training and improvement in the ability to tap the rhythm.

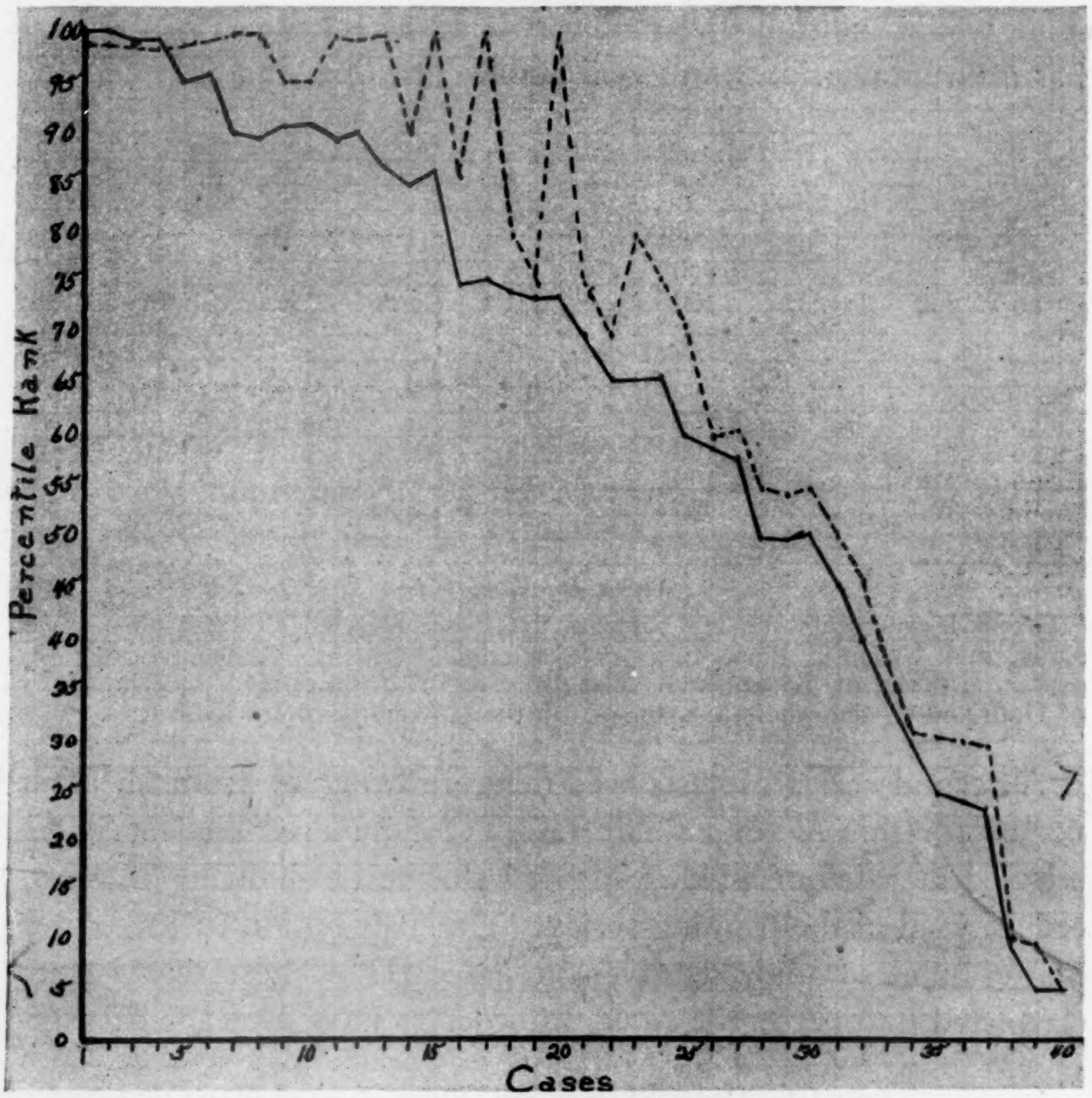


CHART II

The scores of the ten poor students and the scores of the ten good students were arranged in percentile ranking in order to determine the relation between musical success and performance in this test. The two groups are listed in Table II, giving their

percentile rank, rating in the music school, and their particular field of music. The results of this ranking show that the ten superior students have a percentile rank ranging from 65 to 100 with an average of 90. The ten poor *Os* have a percentile rank ranging from 30 to 80 per cent, with an average of 60 per cent. This would indicate that motor rhythm as measured in this test has a direct relation to musical ability and performance.

TABLE II. *Percentile ranking of twenty music students*

| *Group 1* Field of music | Rank | *Group 2* Field of Music | Rank |
|---|---|---|---|
| Professor of piano | 100 | Voice student | 80 |
| Piano student | 100 | Piano " | 70 |
| Piano " | 100 | Voice " | 70 |
| Voice " | 95 | Violin " | 70 |
| Violin " | 90 | Piano and voice student | 65 |
| Piano " | 90 | Piano student | 65 |
| Piano " | 90 | Voice " | 60 |
| Piano " | 90 | Cello " | 55 |
| Violin " | 85 | Voice " | 30 |
| Piano " | 65 | Piano " | 35 |

*Legend for Table II*

Group 1 represents the ten students that were selected as superior in their study, and Group 2 those that were selected as poor. Rank indicates the percentile rating of the students. The professor of piano is from the University of Utah and all the others are students in the University of Iowa.

A second series of tests was made in order to establish adult norms for this motor rhythm test. One hundred students were selected at random and were given this test, following the procedure used in the training series. The distribution of the scores of the hundred adults is given in Table III. These scores were converted into percentile ranks in order to have a means of com-

TABLE III. *Distribution of raw scores on rhythm test*

| A.M. | Adults | A.M. | Adults |
|---|---|---|---|
| 15–16 | 3 | 37–38 | 6 |
| 17–18 | 8 | 39–40 | 3 |
| 19–20 | 10 | 41–42 | 5 |
| 21–22 | 4 | 43–44 | 2 |
| 23–24 | 9 | 45–46 | 3 |
| 25–26 | 5 | 47–48 | 4 |
| 27–28 | 7 | 49–50 | 2 |
| 29–30 | 7 | 51–52 | |
| 31–32 | 9 | 53–54 | |
| 33–34 | 4 | 55–56 | |
| 35–36 | 6 | 57–58 | 1 |
| | | 59–60 | 2 |

parison with other scores and tests of musical ability. This standard also affords a good measure of ability in the test itself and this percentile rank was used in that way in this problem. The following table gives this conversion and rank in percentile.

TABLE IV. *Conversion of raw scores into percentile ranks*

| Adult score | Rank | Adult score | Rank |
|---|---|---|---|
| Complete failure | 0 | 30.5 | 50 |
| 49. | 5 | 28.5 | 55 |
| 46. | 10 | 27.2 | 60 |
| 41.7 | 15 | 25.8 | 65 |
| 40.2 | 20 | 23.8 | 70 |
| 38.3 | 25 | 23.2 | 75 |
| 36.7 | 30 | 20.5 | 80 |
| 34.2 | 35 | 19.7 | 85 |
| 32.3 | 40 | 18.8 | 90 |
| 31.3 | 45 | 17.8 | 95 |
| | | 17.7 | 100 |

The reliability of the motor rhythm test at 60 r.p.m. was determined by a correlation of the scores which the 40 *O*s made on two successive days. The coefficient of correlation was found to be .87, p.e. .03.

*Conclusions.* Capacity in motor rhythm as measured in this test correlates significantly with musical ability and performance. Motor rhythm can be slightly improved, but the improvement all falls within the very early training period. There is no significant relation between ability to tap rhythm and amount of improvement, or between musical training and improvement in ability to tap rhythm.

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# A QUALITATIVE AND QUANTITATIVE STUDY OF THE EMOTION OF SURPRISE[1]

BY
EMILY PATTERSON

*Introduction; experimental studies; apparatus; procedure; quantitative interpretations; qualitative aspect of surprise; individual differences; tentative classification; summary; bibliography.*

*Introduction.* As a result of her study of fear *Bayley* (**4**) made a preliminary differentiation of apprehension and startle from their qualitative and quantitative aspects. We were led to the study of surprise both on the basis of the introspective reports of her *O*s, and through the technique for arousing the emotions.

Psychological treatises in the field of affective experiences discuss rather scantily the emotion of surprise. Some of the points that are discussed are: the nature of the stimulus which provokes it, its place in the classification of the emotions, the character of its facial and bodily expression, and its relation to other complex mental processes.

Most authorities agree that surprise is caused by a stimulus which is sudden, unexpected, or novel. *Stern* (**34**, p. 131) says, "If the familiar sequence of perceptions or the usual order of the association is suddenly interrupted at any one point by a strange impression, the emotional condition of SURPRISE results." *Bain* (**2**, p. 69), *Stanley* (**33**, p. 164), *Shand* (**30**, p. 419), *McDougall* (**24**, p. 344) and *Washburn* (**42**, p. 202), make statements which closely approximate this. All writers stress the fact that the subjective condition of the individual previous to the presentation of the stimulus is important. To have surprise we must first have established associations, memories, and perceptions which are later disrupted.

The place which surprise holds in a classification of the emotions depends on the basis chosen by each author for his

[1] This study was made under the direction of Dr. Christian A. Ruckmick.

own particular system. Two main types of classification prevail, the logical and biological. While admitting to some extent the principle of relativity in all emotions, *Bain* (2, p. 76) classifies them logically as follows: emotions of relativity, ideal emotion, and sympathy. Wonder and surprise are cited as instances of the "emotions of relativity." The objective cause of the "emotions of relativity is a purely relative circumstance." (2, p. 83). The point here made refers to the fact that this type of emotion is a response to a situation which differs only relatively, either in pattern, degree or general texture to a situation just previously experienced or one that is normally to be expected. *Ribot* (26, p. 369) tends more toward a biological view, classing surprise as an intellectual sentiment. "It is a special emotional state which cannot be traced back to any other, consisting of a shock, a disadaptation." He agrees with *Bain* in that he considers the material of surprise to be a "relation," "a mere movement of the mind and nothing more." *Sully* (37, p. 386) and *Stanley* (33, p. 164) also classify surprise as an intellectual emotion. They too mention the factor of disadaptation as important in surprise.

*Darwin* (10, p. 283), as the chief exponent of the biological treatment of the emotions, calls surprise a sudden irruptive emotion, the function of which is to make the individual attend to the exciting object and thus adjust to the new situation. *McDougall* (23, p. 162) likewise mentions the function of adjustment in connection with surprise, but he does not place surprise among the primary emotions. This is because in classifying emotions he pairs each with its corresponding instinct and stresses the conative tendencies of the several emotions. On this basis surprise as well as joy and sorrow must be excluded from the list of true and primary emotions because "surprise is an affective state that implies no corresponding instinct and has no specific conative tendency." Although he adopts a somewhat similar basis for classification, *Warren* (41, p. 299) adds a subdivision, "emotions with temporal projection," for which there seems to be no instinctive basis. Surprise is included under this rubric along with regret and satisfaction.

*Wundt* (47) and *Külpe* (22) present two classifications which emphasize the psychological nature of the emotion. *Wundt* (47, p. 201) distinguishes such emotions as reach their maximum very rapidly and then gradually sink to a quiet affective state from those which rise to a maximum gradually and sink in the same way. Surprise, astonishment, fright, disappointment and rage belong in the first group of sudden, irruptive emotions. According to *Külpe* (22, p. 323) "One extreme is constituted by emotions in which the organic sensations are so completely dominant as to determine the actual character of the emotion. These we may term *objective.* Here belong the processes of expectation and surprise together with amazement."

This wide variation in definition and classification suggests the questions, "What is the actual nature of the emotion of surprise? Is it a 'mere movement of mind' as *Ribot* implies, or is it the consciousness of profuse organic sensations, as *Külpe* claims? What then are the physiological changes which accompany any surprise?" *Darwin* (10, p. 283), in discussing surprise and astonishment, says that "every sudden emotion . . . quickens the action of the heart and with it the respiratory movements." *Shand* (30, p. 427) states that the bodily sensations connected with surprise often survive the emotion, mentioning specifically the quickened heart-beat and breathing. Undoubtedly physiological changes accompany surprise but their exact nature is not clear, although quickened heart-beat and breathing are most frequently mentioned.

Authorities disagree as to the affective tone accompanying pleasantness or unpleasantness of the state of surprise. Most writers, however, cite surprise as an example of an emotion which may be characterized by either quality of affective tone. Thus *Stout* (36, p. 417) and *Warren* (41, p. 299) class surprise as an emotion which may be either pleasant or unpleasant, in contradistinction to fear which is always unpleasant, and joy which is always pleasant. *Stern* (34, p. 132) mentions that the circumstances which accompany surprise determine the affective tone, "Surprise is accompanied by more than one emotion, so that we find joyful, frightened, and more or less indifferent surprise,

although this last has a tendency to turn into pleasure at the novelty or into fear . . . What is perfectly new . . . when once entirely grasped by the child, generally causes pleasure not fear." *Bain* (2, p. 85) also notes that the accompanying circumstances may influence the affective tone of surprise. *Stanley* (33, p. 51), on the other hand, makes much of the fact that all emotions are definitely pleasant or unpleasant; at the time when they are experienced. So he says, " It is to be noted that when we come upon the feeling-element in surprise we find pain." This pain is caused, according to *Stanley* (33, p. 51), more by the subjective factor of having former beliefs disturbed than by the force of the disturbing stimulus. Finally, *Stanley* (33, p. 52) believes that pleasant surprise is merely surprise followed by pleasant consequences. *Sully* (37, p. 386) discusses the affective tone of surprise in a similar manner, noting the unpleasantness of the disturbance and consequent pleasantness or unpleasantness depending on the subsequent emotion. *Allport* (1, p. 95) claims that the fear element is pronounced in surprise and would probably agree that the feeling element is unpleasantness, although he does not mention the affective tone as such.

Attention plays a very important part in the state of surprise. Thus, says *Shand* (30, p. 430), " The effect of surprise is to make us attend to the event that surprises us." *Darwin* (10, p. 278) and *Sully* (37, p. 380) both give intensified attention as the most important component in surprise. Surprise then is closely related to the process of attention. Its relation to other mental processes is not quite so clear cut. *Stanley* (33, p. 50) claims that surprise has a disturbing effect on cognition.

Among psychologists who use the term " conation " for striving or " the felt impulse to action," we find *McDougall* (23, p. 162) and *Stout* (36, p. 417) discussing the relation of surprise to conation. They agree that conation is not particularly present in surprise. In fact, as has been noted above, *McDougall* (23, p. 162) excludes surprise from his list of primary emotions partly on this account.

In summarizing the discussions of surprise we see that they include such various causes as " mental confusion," and " extreme

organic sensations." The physiological accompaniments have been little analyzed. There is considerable disagreement as to its affective tone, it is considered to be a disturbing element in cognition, and to have little or no conative impulse. The basis for determining the subjective nature of surprise has been the examination of one's own processes, while the objective determinations consist wholly in observing facial expressions. The purpose of this study is to make a preliminary survey of the nature of surprise from the introspective reports of several observers accompanied by approximate quantitative measures of certain bodily effects.

*Experimental studies.* Studies which bear on our problem are few in number. *Bayley's* (4) study which led directly to this one reported introspections of surprise quite frequently when "startle" stimuli were given. *Blatz* (5) in his experiment with fear at a sudden unexpected fall, obtained reports of "surprise" from several of his subjects. Neither of these experimenters made an effort to determine the essential elements of surprise, and both investigators treated it as a variant of "startle" or fear.

*Wechsler* (44), in determining the "psychological correlations" of the galvanometer used two stimuli "both of which probably caused surprise." They were: a loud automobile horn hidden under the table and an unexpected flash of magnesium. He found that the deflections of the galvanometer with these two stimuli were more highly correlated than they were with any other two of his stimuli. They were somewhat correlated with the deflection for "orientation of attention," which fact he explains by saying that probably attention plays a large rôle in surprise. He quotes no reports from his *O*s on how the stimuli affected them.

*Apparatus.* The apparatus and electrical circuit used in this experiment were in their essential elements the same as those employed by Bayley (2). The identical galvanometer and Wheatstone bridge were used. The physical variables in the circuit were carefully checked, however, in order to assure ourselves that the only variable was *O*. One cell of a standard storage battery maintaining a potential difference of two volts was em-

ployed instead of the dry cell, because of the inherent variation in a dry cell which might in itself cause changes during a sitting.

The calomel electrodes,[2] which *Bayley* used were modified for two reasons: we encountered difficulties with the flow of the liquid through the tubes leading to the palm and the back of the hand; and we could not keep the area of contact constant, since liquid would leak from the tubes, sometimes running down the hand. We avoided these difficulties by having *O* dip two fingers, the index and the ring, of the left hand into the electrodes. The fingers were wound with insulating tape proximally from the first joint, so as to maintain a constant area of immersion during a sitting. *Wechsler* (43) has also pointed out that the "curve of rest," that is the curve taken when *O* is normal and no affective stimuli are given, when taken from the finger tips is flat, whereas when taken from the palm it rises at first and then falls for an indefinite period of time.

This improvement in contact with the elimination of the high resistance in the tubes leading from the electrodes to the hand made the galvanometer more sensitive, in fact too sensitive. Many of the deflections were so extensive that they could not be recorded. We therefore reduced the sensitivity of the galvanometer by connecting a small constant shunt with a resistance of .1 ohm across the galvanometer instead of the variable shunt previously used. The results for the various *O*s were made comparable by *Smith's* (32) [3] technique for handling variations in resistance between *O*s and in the same *O* on different days.

Technical difficulties of recording the deflections were eliminated as much as possible, thus making the records more accurate. The drum which carried the recording paper was recentered and made more stable. A firm holder for the bar on which the recording pen slides was constructed as well as a rigid pointer extending from the pen to the mirror scale. Siphon pens, which

[2] These were of the Ostwald type, which prevent polarization, and were adapted to our requirements by Dr. J. N. Pearce of the Department of Chemistry of this University. A complete description of the electrodes is given by Ruckmick, C. A., and Patterson, E. A simple non-polarizing electrode. *Amer. J. Psychol.*, 41, 1929, 120–121.

[3] See also *Bayley* (4, p. 15).

have been adopted in other experiments in our laboratory, were used for the time and stimulus lines, instead of the miniature fountain pens previously employed. The reader, relieved of periodically attending to the pens, could devote his time to making an accurate record of the light which indicated the deflections.

For the second series of experiments a cable connection was made to the sound-proof room. This enabled us to have the electrodes in the sound-proof room while the reader recorded the deflections as before. Also a signal circuit was wired from the sound-proof room to the room in which the galvanometer was set up.

*Procedure.* *E* taped the ring and index fingers of *O*'s left hand proximally from the first point with insulating tape, and cleansed *O*'s fingers with cotton dipped in alcohol. She then read the following directions to *O*:

Take a comfortable position in this easy chair so that you will not have to move any more than is necessary. Under no condition will you receive a shock from the apparatus which is attached to the fingers of your left hand. A number of situations will be presented during the experimental period. Note carefully your reaction to each situation, naming it, and rating its intensity on a scale of ten, with ten very intense, five moderately intense, and zero indifferent. Note whether the experience is pleasant or unpleasant. Also remember any muscular tensions or relaxations and their location, organic sensations, as well as secretory changes. Take note of images and ideas and their nature. You will be asked to make a report at the end of the sitting.

Situations that were used in approaching the problem of the nature of surprise were:[4]

A soft record was played. In a particularly quiet passage a pile of scrap tin was dropped on the floor. (Clatter.)

A ghost story was read, in the middle of which had been inserted some material from a mathematics book. (Change in story.)

*E* threatened to burn *O* with a match, but after she had lighted it, said, "I really haven't the nerve to burn you," and dropped the lighted match into a tray containing flash powder. The match usually ignited the flash powder, causing a sudden flare of light. (Flash)

**[4] A key word is given in parenthesis after each situation. The situation is denoted in Plate I by this key word.**

*E* told *O* that she was going to paint his tongue with vinegar. She took a brush and small jug from the cabinet, asking *O* to hold the jug. It was three-fourths full of mercury and was therefore unexpectedly heavy. (Mercury)

*E* gave *O* a book of classical prints to look at. As *O* was perusing one of the prints, *E* pointed a pistol at *O*, bringing it gradually around into the field of direct vision.

*E* threatened to burn *O* with the flame of a cigarette lighter. As *E* opened the lighter—which was, in reality, a trick match box—it fell completely apart. (Match box)

*E* said, "O, I forgot some apparatus I need," and left the room, returning in about a minute. As she came in, she tripped over the door sill, dropping the apparatus. (*E* stumbled)

*E* gave *O* a square root problem to work. As *O* was in the midst of it, *E* jerked it away, tearing it up. (Tearing problem)

A record was played half through when *E* said, "This is too loud, it's probably disturbing the man next door. I'll turn it over, for the selection on the other side is softer." She turned over to a Seashore consonance test. (Seashore record)

*E* informed *O* that Dr. Ruckmick had made out some questions in order to discover how well he was keeping up in his psychology course. *E* said, "These will be hard," waited a moment, then said in a loud voice, "bla, bla, bla." (Change in voice)

In two cases *E* presented the unpleasant odor of asafoetida to *O* when he had been led to expect a pleasant one. (Odor)

Three *O*s were told of their election to Sigma Xi, an honorary scientific society, in the experimental situation. (Announcement)

In one case a notebook, which *Ht* had lost two months previous to his observation, was returned. (Notebook)

In several cases a sharp whistle was blown as a startle stimulus. (Whistle)

These situations were not used on all the *O*s because some observed more times than others, and we were continually augmenting our technique.

From the above situations we obtained suggestions as to the elements of a typical surprise situation. The preliminary introspective reports and galvanometric readings furnished us with a

cue on the basis of which we proceeded to refine the technique. In order to do this effectively, we devisd a situation which involved the important elements that were predominant in previous surprises. Twenty-one students, with varying degrees of training in psychology, observed in this series.

The procedure here was similar to that given above, except that *O* was told that *E* was going to make a reading of changes in the skin under very well controlled conditions, and that for this purpose she would take him to the sound-proof room where there was only a very dim light. *E* then taped the fingers, and read the directions, as before, except that these were slightly altered to suit the situation, in that the first three sentences were omitted, and the first sentence of the new directions read, "If anything occurs which would make you feel differently from normal, note your reaction, naming it if possible." *E* then took *O* into the sound-proof room. She made sure that *O* was seated comfortably. She then left the room to balance the Wheatstone bridge, start the motor and the chronoscope. In about two minutes *E* returned to the sound-proof room, where only a dim light shone through a black curtain which hung about five inches in front of *O*. *E* sat on a stool about three feet in front and two feet to the left of *O*. She then said, "Back of this curtain and about ten inches below this light I have a skull all painted up with phosphorescent paint. I'm sure you'll get quite a thrill out of seeing it. Fixate about ten inches below the light, then I'll turn out the light and withdraw the curtain." *E* extinguished the light, and withdrew the curtain. As she did this she turned a flashlight on the side of *O*'s face, thus causing it to reflect in a mirror which was placed just where *O* had fixated for the skull. *E* actuated the signal magnet at the instant the light was thrown on *O*'s face. After waiting about a minute *E* replaced the curtain, turned on the dim light and said, "Now for purposes of control I am going to show you your face a second time." *E* turned out the light again, and withdrew the curtain to reveal a lighted skull.

In two cases (*Wb* and *Pl*) *E* omitted the description of the skull and merely said, "There is something back here on the table that I want you to see. I will withdraw the curtain and show it

to you." Even in these two instances surprise was reported because as *Wb* said, " Seeing myself was the last thing I expected."

That our predictions concerning the effectiveness of this situation in causing surprise were correct is shown by the fact that twenty out of twenty-one *O*s spontaneously reported surprise in such terms as those of *St,* " I'd call it a grand surprise," or of *Nw,* " I was totally surprised." *Mo* reported, " I was very much surprised," and *Hs* named the experience as " great surprise bordering on startle."

In five cases a sharp whistle was blown as a final stimulus to give us some basis of comparison with startle.

In only one case did the seeing of the skull arouse surprise. This was due, according to the reports of the *O*s, to the fact that by this time they were suspicious of *E* and also to the fact that the total setting was one in which the presentation of such an object as a skull would seem highly probable, for as *Hk* reported, " There was a certain wierdness about the whole situation."

*Quantitative interpretations.* No refined statistical treatment of the galvanic results was justified, but we thought that some comparisons might be made on the basis of the procedure suggested by *Smith.* The deflection for each *O* was multiplied by the initial resistance of that *O* as determined on the Wheatstone bridge. The mean of these products was then computed and a single product expressed in terms of the per cent. of the mean of the products.[4]

We then listed the emotions reported by the *O*s. We arranged the emotions according to descending order of magnitude of the average galvanometric deflection produced. The range of percentages is noted in each case as well as the number of times the emotion was reported. The results are shown in Table I.

The single case of joy (*Ja,* announcement of election) falls at the top of the list followed by surprise with fear, fear and startle, amazement, alarm, startled surprise, astonishment, and surprise. Thus seven emotions show larger galvanometric changes than does surprise. Aside from the one instance of joy, there seems to be a gradation of emotional reactions to sudden, unexpected

[4] *Smith* (32) explains and justifies the use of this method for the purpose of comparing the galvanometric results obtained from various *O*s.

TABLE I. *Galvanometric readings for emotions reported*

| Emotion | No. Cases | Mean Score | Range |
|---|---|---|---|
| Joy | 1 | 402 | |
| Surprise with fear | 1 | 271 | |
| Fear and startle | 8 | 229 | 31–888 |
| Amazement | 2 | 226 | 73–374 |
| Alarm | 1 | 212 | |
| Startled surprise | 2 | 146 | 97–195 |
| Astonishment | 1 | 114 | |
| Surprise | 22 | 102 | 0–434 |
| Amusement | 1 | 76 | |
| Pain | 2 | 72 | 38–106 |
| Annoyance | 1 | 69 | |
| Distaste, disgust, dislike | 6 | 67 | 0–133 |
| Dread and apprehension | 4 | 47 | 0–133 |
| Wonder | 5 | 29 | 0–68 |
| Relief | 4 | 27 | 0–115 |
| Frustration, feeling of absurdity | 2 | 10 | 0–19 |
| Indifference | 4 | 15 | 0–28 |
| Resentment | 1 | 0 | |
| Sympathy | 1 | 0 | |
| Dejection | 1 | 0 | |

stimuli, the descriptive names depending somewhat on the component elements. Except for the emotion of joy, the emotions which show the largest changes have in every case an element of fear. Although our technique was not intended to arouse fear, it was reported in nine cases specifically, and in some form or other may have been present in the cases of amazement, alarm, startled surprise and astonishment. Since the same situation evoked in some *O*s the fear response and in some surprise, fear was probably rather closely related to surprise.

Surprise includes a very large range of deflections (0–434) and the galvanometric readings indicate that there is much overlapping from one emotion to the other. Thus it is impossible for us to differentiate surprise from other emotions solely on the basis of our quantitative results. This may be due in part to the variations in effectiveness of the several situations with the same *O* and with different *O*s.

We consequently ranked the subjective ratings given by *O* and obtained, by the rank-order method, the relationship between the subjective ratings and the deflections. The following formula was used to obtain rho ($\rho$):

$$\rho = 1 - \frac{6 \Sigma D^2}{N(N^2 - 1)}$$

We translated the values obtained for rho into r's. The probable errors of these r's were then found with the use of the formula:

$$P.E.r = \frac{.7063\ (1 - r^2)}{N}$$

TABLE II. *Correlation, for each observer, of intensity ratings with the extent of the galvanic reflex*

| *O* | rho | r | P.E. of r |
|---|---|---|---|
| *Ha* | .696 | .716 | .114 |
| *Ht* | .566 | .588 | .163 |
| *Ja* | .786 | .803 | .088 |
| *Kl* | .638 | .657 | .134 |
| *Lck* | .866 | .879 | .060 |
| *Mlr* | .846 | .861 | .060 |
| *Pl* | .514 | .527 | .153 |
| *Wb* | .564 | .578 | .141 |

The results for each *O* are shown in Table II. The values of r vary from .527 ± .153 to .879 ± .060. Although rho indicates merely the presence of a relationship, not the extent of the relation, all these values are significant. It would seem a reasonable conclusion, therefore, that at this stage of progress the extent of the reflex can be used in some measure to indicate the intensity of the feeling produced, rather than the nature of the feeling aroused. This holds true at least for each *O* when a variety of stimuli have been given.

Since not enough quantitative data were available for each *O* in the second series of experiments to express the results in terms of per cent of the mean, the results from this series were treated in a somewhat different manner. The results are tabulated in Table III. The situation divided itself rather naturally into six parts, indicated on the table as *E* out of room, *E* enters door, description (of skull), reflection, shows skull, and whistle (this last stimulus was used for only 5 *O*s). *O*'s report is divided into two parts, (1) the "state" (emotional or normal) and (2) the intensity of the feeling produced (indicated as I in Table III). This rating was not obtained from all *O*s for each part of the situation, for in giving their reports they stressed the parts of the situation which impressed them most. The galvanometric results are also divided into two parts. Smith's

formula was again used, in that each deflection was multiplied by the initial resistance of *O*. These values were reduced to convenient denominations by dividing in each case by ten thousand. Since, on casual perusal of the records, the distinctive feature seemed to be the suddenness in rise of the curve, the angle at which the curve rose was roughly measured. Due to the method

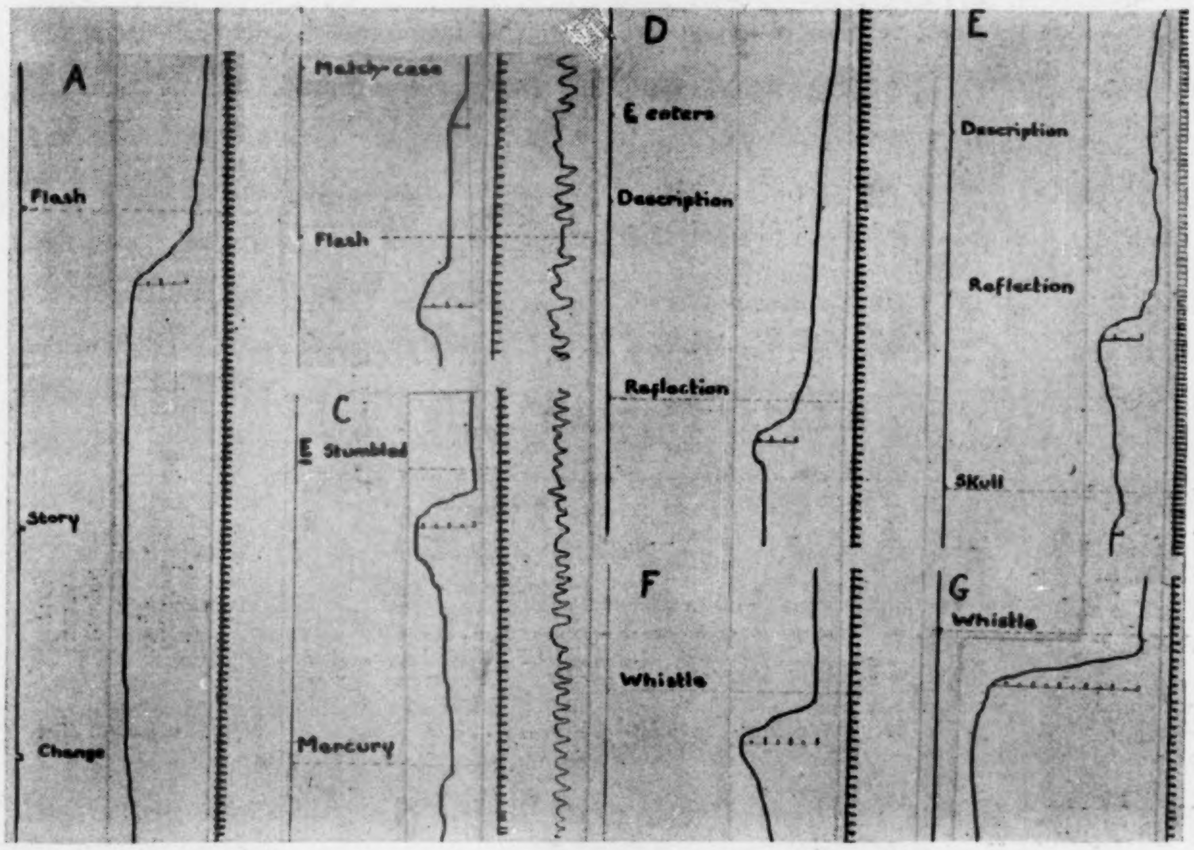


PLATE I

Legend: Plate I shows typical curves. The lines on each record from left to right indicate (1) presentation of stimulus, (2) galvanometric change, (3) time line (interrupted every two seconds), (4) breathing curve (in records B and C).

of recording which was used, these measurements are not considered exceedingly accurate, but we thought that they might give some indication of differences. The mean and average deviation of galvanometric changes for each portion of the situation was then calculated and the results are shown in Table III.

For the first part of the situation, *E* out of room, the mean obtained was 5.74 with an average deviation of 6.9. Six *O*s reported expectancy, three apprehension, three anticipation, two normalcy, one excitement, one drowsiness, and one fear. For

TABLE III

| O | *E* out of room | | | | *E* enters | | | | Description | | | | Reflection | | | | Shows skull | | | | Whistle | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Report | | Galv. | | Report | | Galv. | | Report | | Galv. | | Report | | Galv. | | Report | | Galv. | | Report | | Galv. | |
| | C | I | A | RD | C | I | A | RD | C | I | A | RD | C | I | A | RD | C | I | A | RD | C | I | A | RD |
| | | | | 10000 | | | | 10000 | | | | 10000 | | | | 10000 | | | | 10000 | | | | 10000 |
| Wb | N | | | 0 | Tn | | | 0 | Ep | 5 | 5 | 21.5 | As S | 8 | 55 | 59.2 | P In | | 45 | 24.1 | F | 9 | 85 | 636 |
| St | Ap | 5 | 9 | 13.3 | Ep | | | 0 | Ep | | | 0 | S | 8 | 72 | 36.5 | P In | | 34 | 6.6 | St | 9 | 80 | 175.5 |
| Hs | Ep | | 9 | 7.4 | Ep | | 28 | 19.8 | Ep | | 8 | 7.4 | St S | 9 | 50 | 17.3 | P In | | 18 | 4.9 | St | 7 | 45 | 49 |
| Wm | An | 3 | 5 | 3.6 | An | 4 | 70 | 7.2 | U An | | 33 | 89.5 | S | 6 | 76 | 67.9 | | | | | | | | |
| Ca | Ex | | 10 | 14.5 | Sp | 7 | 10 | 4.8 | Ds | | 10 | 21.4 | Sn | 7 | 67 | 67.8 | | | | | | | | |
| Ma | Ap | 3 | 5 | 5.1 | Ap | | 5 | 5.0 | Ap | | 5 | 5 | S | 5 | 68 | 46.3 | In At | | 39 | 10.3 | | | | |
| Ro | Ep | | | 0 | Ep | | 76 | 17.7 | Ep | | 20 | 38.6 | S | 5 | 54 | 17.7 | In | | 30 | 14.5 | | | | |
| Rt | Ep | 2 | | 0 | Ep | 8 | 72 | 87 | At | 5 | 45 | 17.4 | Da | 3 | 74 | 17.4 | Am | 2 | 28 | 8.7 | | | | |
| Up | Ep | 5 | | 0 | St | 7 | 80 | 111.4 | Ap | 4 | 10 | 10.4 | S | 7 | 65 | 31.1 | In | 2 | 20 | 13.0 | | | | |
| Pl | An | 2 | | 0 | An | 2 | 70 | 17.1 | Im | | 20 | 17.1 | S | 8 | 47 | 30.9 | U | 2 | 22 | 6.9 | | | | |
| Nl | Dw | | | 0 | Ep | 3 | 18 | 10 | An | 2 | 30 | 5.0 | Rl S— | 2 | 35 | 45.9 | Am | 2 | 50 | 20 | | | | |
| Ch | N | | | 0 | N | | 8 | 8.9 | N | | 11 | 4.4 | S | 2 | 11 | 8.9 | S | 5 | 40 | 8.9 | | | | |
| Mt | Qu | | | 0 | | | 40 | 24.3 | Dl | 3 | 12 | 13.1 | S | 5 | 78 | 39.3 | | | 75 | 39.3 | | | | |
| Nw | Ep | 2 | | 0 | Ep | | 60 | 16.4 | Pr | | 48 | 16.4 | S | 6 | 28 | 11.0 | In | | 35 | 8.2 | | | | |
| Lr | Ep | 2 | 18 | 11.2 | Ep | 2 | 55 | 15.6 | Sl D | | 15 | 40.1 | S | 6 | 58 | 17.8 | S | 3 | 61 | 17.8 | St | 8 | 65 | 150.4 |
| Ps | Ep | 3 | | 0 | Am | 2 | 74 | 11.4 | Am | 2 | 15 | 11.4 | S | 2 | 43 | 5.7 | Am | 2 | 12 | 3.0 | | | | |
| Hk | Ap | 3 | 23 | 38.9 | Ap | | 42 | 18.8 | Ap | | 26 | 46.9 | S | 6 | 55 | 30.8 | Cu | 2 | 46 | 8.0 | | | | |
| Tf | Ep | | 19 | 14.9 | Ep | | 71 | 14.9 | Ep | | 17 | 10.4 | S | 8 | 78 | 114.7 | At | | 75 | 52.2 | | | | |
| Ht | An | 3 | 20 | 5.9 | An | 3 | 55 | 6.9 | Db | | 20 | 4.7 | S | 8 | 58 | 21.3 | | | | | | | | |
| Jk | Ep | | | 0 | Ep | | 8 | 9.0 | Ep | 4 | 6 | 11.2 | S | 5 | 60 | 38.2 | | | | | St | 8 | 70 | 93.5 |
| Mo | F | 8 | | | St | 8 | 58 | 10.7 | Ap | 5 | 30 | 16.1 | Rl S | 5 | 56 | 8.0 | Sl F | 5 | 60 | 21.4 | | | | |
| Range | | | 0-23 | 0-38.9 | | | 0-80 | 0-111.4 | | | 0-48 | 0-89.5 | | | 11-78 | 5.7-114.7 | | | 12-75 | 3-52.2 | | | 45-85 | 49-63.3 |
| Mean | | | | 5.74 | | | | 19.85 | | | | 19.43 | | | | 34.90 | | | | 15.751 | | | | |
| Ave. deviation | | | | 6.9 | | | | 15.6 | | | | 14.3 | | | | 19.6 | | | | 8.9 | | | | |

*Legend:*

- A Angle of deflection
- Am Amusement
- An Anticipation
- Ap Apprehension
- As Astonishment
- At Attention
- C Affective condition
- Cu Curiosity
- D Dread
- Da Disappointment
- Db Doubt
- Dl Dislike
- Ds Disbelief
- Dw Drowsy
- Ep Expectation
- Ex Excited
- F Fear
- I Degree of intensity
- Im Imaged
- In Interest
- N Normal
- P Passive
- Pr Preparation
- Qu Quiet
- Rl Relieved
- $\frac{RD}{10000}$ Smith's formula
- S Surprise
- Sl Slight
- Sn Stunned
- Sp Suspension
- St Startle
- Tn Tense
- U Unpleasant

section two, *E* enters door, the mean was 19.85, with an average deviation of 15.6. Here seven *O*s reported expectancy, three anticipation, two apprehension, two startle, one tenseness, one suspense, one wonder, one amusement and one a normal condition. The high mean as compared with the first of the situation was partly due to the startle reported by *Up* as being of considerable intensity, for if we neglect this deflection the mean is reduced to 15.2. The mean deflection during the description was 19.43. Expectancy, apprehension, dread, dislike and doubt are reported here. For the situation with mirror, the part of the situation in which we are most interested, the mean is 34.9, with an average deviation of 19.6. The subjective reports name surprise, disappointment, relieved surprise, and stunned. This mean is considerably larger than any of those preceding. The subjective ratings of intensity are also larger, showing that this part of the situation was more effective with most of the *O*s. For the skull situation, the mean drops to 15.8 with an average deviation of 8.9. The mean again corresponds somewhat to the subjective ratings of intensity which are smaller than those for the stimulus of the mirror.

We find here again evidence that the amount of deflection is related in some way to intensity of feeling produced, although the rank order correlation obtained from relating subjective ratings of intensity of feeling produced on seeing the reflection, with galvanometric deflections yields a rho of only .332. This becomes an r of .344 ± .126, which is not in itself significant. But when consideration is taken of the fact that the subjective ratings in this case were obtained from different *O*s, all of whom were rating their experience according to a different standard, the fact that any correspondence at all was found appears significant.

In spite of the fact that Smith's method was intended to reduce the deflections of the various *O*s to comparable values, it appeared from casual inspection of the records that some *O*s gave larger deflections for each portion of the situation than others. We therefore again used the rank method and obtained correlations between the quantitative measures for the first three parts of the situation and the seeing of the reflection, as well as between those for the seeing of the reflection and the skull. The

rho for the reflection *versus* the previous three was .07, giving an r of .073 ± .144, while that of the skull *versus* the reflection was .382 yielding an r of .393 ± .144. The first relationship was unexpectedly low, and shows, perhaps, specificity of emotional reaction, in that some *O*s will react emotionally (with physiological accompaniments as shown by galvanometric readings) to one situation and not to another. It may be interpreted as indicating that apprehension, expectancy, and anticipation, which were most frequently reported in the first part of the situation, are not related to surprise as shown by the physiological change produced, which is recorded by the galvanometer. The fact that the galvanometric changes produced on seeing the reflection and seeing the skull are somewhat more related may be due to the common factor of attention. A more detailed and analytical study needs to be made to determine these relationships. It must always be remembered, however, that the galvanometer registers only a restricted bodily effect.

The results obtained from the measurements of the abruptness of rise in the curves are indicated merely by the range of angles for each group, as this measure was considered as being entirely too rough to be treated in any statistical manner. The range of degrees for part one was 0–23, for part two 0–80, for part three 0–48, for part four 11–78, for part five 12–75, and for part six 45–85. The 80 degree angle in part two was obtained from the measurement of the " startle " reported by *Up*. If it is neglected the range is 0–76. The only indication here is that the curve for surprise was on the whole more abrupt than that for apprehension and less abrupt than that for startle. Again overlapping is found to a large extent, so these results are not conclusive.

Therefore, extremes such as apprehension and startle may be differentiated, but surprise lies somewhat on middle ground and can not be set off. Qualitative analysis may give a better basis for differentiation.

*Qualitative aspect of surprise.* Since our situations were developed from the theoretical distinctions made by the various authors as well as from situations in daily life, we thought it profitable to see how many of the situations used actually produced surprise and to discover from the reports of the *O*s the

essential elements in a situation that cause it to be surprising. Although all our situations except the whistle were intended to arouse surprise, the fact that nineteen emotions are listed in Table III shows that they did not arouse the emotion intended in every case. Some excerpts from the introspective reports indicate necessary elements in a surprise situation. *S* states, "Lack of harmony with the rest of the environment but with no implied harm gives surprise." When the tin was dropped during the music *M* said, "I expected something of the sort and I was relieved to have it over." There was no surprise here, only relief. The second series, in which the skull was presented to arouse surprise, but actually aroused surprise in only one case, throws still more light on our problem. *Pl* said, "I expected something like a skull, because it seemed so appropriate in this atmosphere." The reflection of *O* in the mirror caused surprise because as *St* remarked, "O, I was surprised. That was the last thing on earth I expected to see." So it is the unexpectedness of the situation that caused surprise, and the disturbance of the previous condition of *O*. The subjective condition of *O* is more important than the actual stimulus or physical situation.

The bodily changes which accompany surprise vary considerably, both in different situations and in different *O*s. There is, however, greater agreement in the reports of a single *O* for the several surprises than between the various *Os*. Kinæsthetic sensations were most frequently reported. In many cases there was a sudden bodily contraction or relaxation, generally localized, but with individual variations as to specific locus. *Ht,* for example reported, "My shoulders contracted, my head jerked back." *Hs* reported likewise, "I had kinæsthetic sensations from my head jerking to the side." *Jk* noted a "sudden release of tensions in the muscles of the chest." Quite frequently catching and momentarily holding the breath is noted, as *Hs* reports, "I caught and momentarily held my breath." Another locus for kinæsthetic sensation which several *O*s noted is the muscles about the eyes. *Jk* said, "I had sensations of strain in the muscles about my eyes, connected with opening my eyes wider," and in another situation (the flash), "I closed my eyes very tight." *Hs* reported kinæsthetic sensations from blinking her eyes.

Sensations which *O*s reported in fear, startle and anger seem to be relatively infrequent in surprise. Such sensations are organic sensations, temperature sensations, as paling and flushing and tingling sensations. Organic sensations, which were often reported in fear, were noted in only two cases in the reports of surprise. Here the experience was labelled " startled surprise " and both *Ht* and *Hs* reported the " sinking sensation " in the stomach.

Bodily sensations do not seem to constitute the main body of the emotion of surprise, for the reports show that there is much ideational material present. During the actual surprised state this consists mainly in brief phrases of a subvocal (verbal) nature, as *Ht* says, " Well, I'll be damned," and *Hs,* " What happened? " and *Pl,* " Goodness." Subsequent to the actual surprise, ideational material is quite plentiful and is reported with large individual differences in its nature, by all *O*s. This shows that as compared with fear and anger, surprise did not seize the entire course of consciousness. The mental life is not so completely overwhelmed but that ideational processes soon gain the foreground of consciousness. *Wb* contrasted surprise with startle by saying that " surprise is more mental in its nature than startle."

This brings us to the problem of adjustment and its relation to surprise. In surprise there is probably a brief maladjustment which is reported as being unpleasant. Rapid adjustment takes place and ideation occurs. This is brought out quite clearly in the report of *Nw* (in Series B), " The experience was unpleasant, because it wasn't what I was prepared for. I had a verbal idea ' something's gone wrong.' Almost immediately I realized that it was meant to be this way and I was amused."

This maladjustment is brief, giving the unpleasant affective tone. Some untrained *O*s fail to report this, and only report the subsequent ideas and feeling tone. When the subsequent ideation takes place the affective tone changes rapidly to pleasant or continues unpleasant, as the case may be. Thus the dropping of the tin caused *Ht* to be surprised, then irritated and the unpleasant affective tone remained, whereas in most cases the reflection of *O* in the mirror resulted in amusement with a pleasant affective

tone. *Ro* reported disappointment in this situation, however, with an unpleasant affective tone throughout. So surprise, as such, seems to be unpleasant, with a rapid subsequent shift to pleasantness in some situations.

Our introspective protocol gives no evidence of a conative tendency. *O* is caught, but has no desire to run away as in fear.

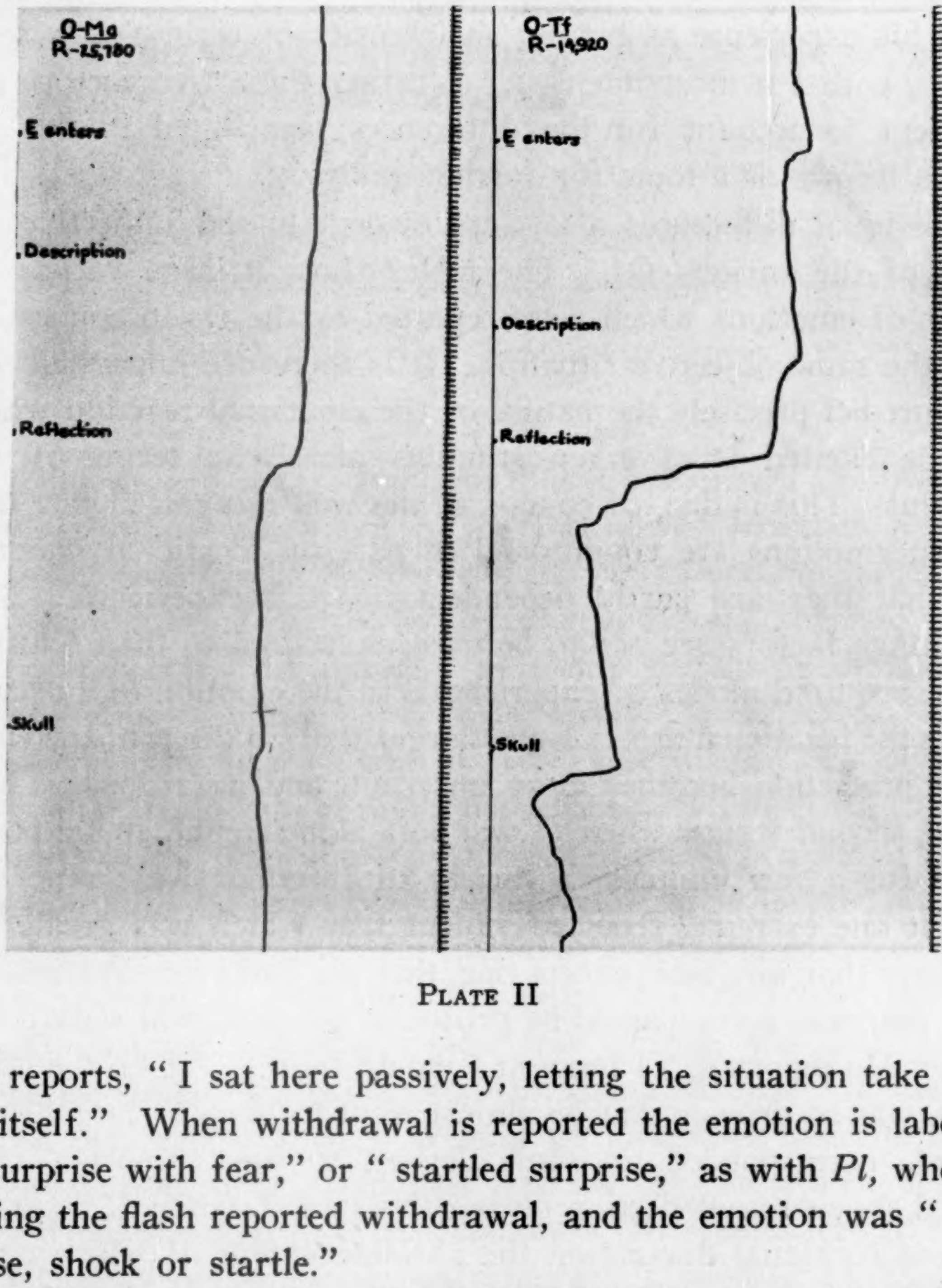


Plate II

*Ch* reports, "I sat here passively, letting the situation take care of itself." When withdrawal is reported the emotion is labeled, "Surprise with fear," or "startled surprise," as with *Pl,* who on seeing the flash reported withdrawal, and the emotion was "surprise, shock or startle."

*Individual differences.* Plate II shows extremes of individual galvanometric reactions. These differences may be due in part to the difference in initial resistance of the two *O*s for, according

to *Smith* (32), the higher the initial resistance the less the extent of the galvanic change. *Ma's* initial resistance was 25780 Ω while *Tf's* was 14920 Ω, but even when allowance was made for this (as shown in Table III) the quantitative measures differ considerably. Another factor is the difference in the subjective rating. *Ma* rated her emotional experience on seeing the reflection of her face in the mirror as having an intensity of five, while *Tf* rated his experience as having an intensity of eight (on a scale of ten, with ten most intense). Whether these two factors are sufficient to account for the differences manifested in the objective records is a topic for further study.

Individual differences also were evident in the subjective reports of the various *O*s. The tables show a large variety of names of emotions which were reported by the *O*s in connection with the same objective situation. It is therefore impossible for *E* to predict precisely the nature of the emotional reaction which will be elicited by a given stimulus merely in terms of the stimulus. This is due, of course, to the well recognized fact that human emotions are conditioned in part on ideational material and that they are partly dependent on past experience. The hereditary factors are not to be overemphasized to the exclusion of the acquired modes of experience. In the emotion of surprise, where the ideational aspect looms larger than in the primary emotions, prediction becomes more uncertain and hazardous. Thus, in the second series, when *O* was left alone in the sound-proof room for a few minutes, a variety of reactions were reported. *Mo,* at one extreme, reported violent fear which was greater in intensity than any fear, except one, that she had ever experienced. This fear was accompanied by profound physiological sensations, in fact *Mo* reported, " I thought I would faint." *Nl,* on the other hand, was so drowsy that he almost went to sleep. The galvanic records corresponded, in some degree, to their reports. *Nl's* record showed no deflection during this period, while *Mo's* graph showed continual fluctuation the absolute extent of which could not be recorded on account of the difficulty encountered with balancing the Wheatstone bridge. This difficulty was very likely due to the fact that the physiological reactions were so violent. According to notations given by these *O*s their reactions (*Mo,*

extreme fear, and *Nl* drowsiness) to the experimental situation indicates in some measure the amount of emotion aroused in the situations of daily life.

*A tentative classification.* The quantitative and qualitative analyses gave us a cue for classification, but more data need to be collected concerning various types of emotion before anything but tentative distinctions can be drawn. An attempt is made in the following diagram to present our data, as well as those of Bayley (6), in a classificatory schema.

*Predominantly ideational* *Predominantly sensory*

Fear: Apprehension Dread Typical fear Startle

<——|———|———|———|———>

Surprise: Ideational surprise Sensory surprise

<———|——————|———>

Thus we find certain emotions, like apprehension and ideational surprise whose chief factors are ideational. In other emotions, like startle and sensory surprise, the bodily accompaniments are more prominent. It will be seen that ideational surprise is even more typically "ideational," in terms of our qualitative and quantitative reports, than is apprehension; while startle is much more typically sensory than is sensory surprise. This classification has arisen out of both the quantitative measures and the reports of the *O*s. The galvanic reflex which is aroused in connection with the emotions which were classed as predominantly ideational is of lesser extent than that aroused in connection with those classed as predominantly sensory. *O*s report profound bodily sensations during typical fear, startle, and that form of surprise which has fearful and startling elements. On the other hand they report a large amount of ideational material during apprehension, dread, and that type of surprise which is designated as ideational surprise. Darrow's (9) studies lead to similar conclusions regarding the galvanic reflex aroused by ideational and sensory stimuli.

*Summary.* An improved technique for recording the emotions by means of the galvanometer was devised. The electrodes used in experimentation with the galvanic reflex were definitely modi-

fied, so that the measure of electrical changes was taken from a constant area of the tips of the fingers. The advantage of this technique is that changes in the amount of pressure and in the area of contact are eliminated.

A procedure was developed for effectively bringing surprise and related emotions into the laboratory.

Some evidence has been deduced showing that the galvanic reflex is a reliable though partial measure of the intensity of the emotional experience.

Our data do not give an objective basis for the differentiation of surprise from fear and startle. It would seem that extremes in reaction, such as apprehension and startle, may be partially differentiated in terms of the galvanic reflex, but that surprise can not be sharply distinguished from other emotions on the basis of our quantitative results.

Additional material is presented to support previous results that fear stimuli, especially those of a " startle " nature elicit the most frequent, extensive, and sudden galvanic changes. A single instance of joy is reported, however, which also aroused a wide galvanic response. This indicates that the pleasant emotions which were formerly brought into the laboratory may not have been as effective as the unpleasant ones.

A preliminary qualitative analysis of surprise has been made. This indicated that surprise comprises more of the ideational factors and fewer of the organic components than do startle and fear.

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# PITCH-PATTERNS AND TONAL MOVEMENT IN SPEECH[1]

BY

ALFRED R. ROOT

*Setting for the present study; purpose; approach to the problem; approaches.*

*I. Perception of pitch; procedure; constant, repeatable stimuli; trained Os with good hearing; objective statement of Os' reports; procedure in observations; reliability of perceptual analysis; statement of Os; graphic representation; statistical treatment; perceived pitch patterns in single syllables; perception of speech melody; summary.*

*II. Physical frequency patterns; procedure; apparatus; method of reading; errors in reading; errors in recording; plotting wave-length readings; selection of material for photography; gross physical frequency patterns; pitch periodicities; summary.*

*III. Relationship between physical and perceptual pitch patterns; procedure; statements of general relationship.*

*General conclusions; bibliography; plates.*

*Setting for the present study.* Empirical descriptions, studies of the perceptual and of the physical character of the pitch factor in the human speaking voice have been concerned with the following general problems:[2] the relationship between speech and music; the nature of pitch-patterns and of inflection in continued discourse; the range, direction and peculiarities of pitch changes; sex differences and level of pitch used; the pitch factor in emotional expression; differences in meaning with changes in inflectional pattern; speech melody; tonality and noisiness; definiteness *vs.* indefiniteness of perceived pitch; adequacy of the concept of intervals in pitch changes; relationship of perception of speech melody to the hearer's habits of inflection; relative contributions of vowels and consonants to pitch changes; relationship of pitch changes to intensity changes; periodicities in pitch fluctuations; differential characteristics in pathological conditions and among the deaf; and comparative studies of various linguistic groups.

[1] I wish to make acknowledgment to Dean C. E. Seashore, who served as counsellor during this study, and to the observers used in experimentation.

[2] A forthcoming article will give an historical survey of these studies.

After the experimentation of the present writer had been completed, the report of *Peter's* (11) investigation of the perception of speech melody became available. It is similar in many respects to the present study. In it three methods of reporting the perception of the reproduced speech of phonographic records were used; namely, " pure hearing " method, graphic notation, and the comparison of the pitch of the speech sounds perceived with tones of an harmonium. Statements of general relationship were made between perceptual pitch-patterns and the physical frequency-patterns of the speech material used.

Of the nature of pitch all instrumental approaches have agreed that speech has a gliding character. On the other hand, common observation and the results of ear-analysis suggest that more or less definite points of limit of dominance are heard, which in succession give the impression of melody. Empirical descriptions have attributed intervallic relations to pitch transitions. Yet instrumental studies have given no consideration to them. Perceptual analyses have failed to mention them. The subject of pitch periodicities has but recently been opened, although a definite tremulousness under certain conditions has been a matter of common observation. The study of " meaning " through inflectional variations has contributed but scattered results. The æsthetics of speech has been practically untouched because of a lack of a definite base from which to make an objective approach.

*Purpose.* It is quite clear that before the grosser aspects of speech melody, the communication of " meaning " through inflection and the larger problems in the æsthetics of speech can be satisfactorily investigated, basic facts concerning the nature of pitch-patterns and tonal movement should be well established. To secure them was the purpose of the present study.

*Approach to the problem.* The selection of a small unit of analysis is the first requisite. It furnishes a basis for comparison of definite patterns of intonation and affords a means for the description of larger melodic patterns. The speech *syllable* is a functional unit, which, from an expressive and impressive point of view, was selected as the smallest analytical unit, or a pitch-

pattern of the first order. Each syllable, in spoken discourse, is a unitary response[3] in which there is a successive blending of a number of sounds and may thus be considered as a unit pattern. It is recognized, of course, that the isolation of a single syllable from its complete environment does not completely depict its character or function; yet it does afford a fairly well-defined working unit.

*Approaches.* Vocal speech is a mode of expression as well as a field of impression. A complete description, therefore, would include the point of view of the speaker as well as that of the listener. The most effectual approach to the former lies in a study of the sound waves which the action of the vocal musculature produces. Such an approach has already been extensively employed in a study of music and affords a rigid, quantitative statement of all the devices and subtleties which the singer, like the speaker, utilizes. On the side of perception, analysis can readily be made from the recorded speech which is reproducible with a high degree of faithfulness. But in addition to the physical and perceptual approaches, there is a third way open. Just as in voluntary action of any kind there are involuntary movements which occur, so too in perception, the physical description of sound waves may not represent what the ear perceives. It is a well known fact that the ear permits variations to pass by unnoticed. There is value, then, in discovering the relationships between the physical composition of the speech sounds acting as stimuli and the patterns of pitch which are perceived. These three approaches, then, have been followed in this study:

1. The perception of pitch-patterns and tonal movement.
2. Physical measurements of frequency-patterns and changes.
3. The relationships between the physical and the perceptual pitch-patterns.

With each approach the purpose was to discover the nature of pitch patterns and tonal movement (1) within single syllables, and (2) in transitions from syllable to syllable.

[3] From a psychological point of view a larger ligation of sounds, such as words and phrases, may constitute *Gestalten* of higher orders.

## I. Perception of Pitch

1. *Procedure.* There are three requirements necessary for an objective study of pitch perception in speech: (1) stimuli which are identically repeatable, (2) observers whose capacities for hearing and whose training and ability in observation are somewhat homogeneous and of a relatively high order, and (3) methods of report which will enable comparison to be made among observers and with the physical description of the stimuli, and which are amenable to quantitative treatment.

*Constant, repeatable stimuli.* The modern phonographic recording and reproducing system adequately meets the first requisite. Speech records are available under methods of recording and reproducing which are sufficiently adequate for studies in pitch. A good phonograph motor may run with an error of considerably less than one-thousandth of a second per revolution and is then highly accurate and reliable for reproducing records of all kinds.

The following phonograph records of speech were selected as representative of practically all pitch patterns used in speech:

1. Victor Record No. 16168-B, "Immortality" by Wm. Jennings Bryan.
2. Victor Record No. 75673, "The Merchant of Venice" by E. H. Sothern and Julia Marlowe.
3. Victor Record No. 35256-A, "Who Are the People"; No. 35256-B, "Labor and Capital" by Wm. H. Taft.
4. Victor Record No. 35253-A, "Woodrow Wilson on the Tariff" by Woodrow Wilson.
5. Victor Record No. 20747-A, "Actual Moments in the Reception to Colonel Chas. A. Lindbergh at Washington, D. C." by Graham McNamee, radio announcer for the National Broadcasting Company.
6. Columbia Record No. 49738, "President Wilson" by Rabbi Wise.
7. Columbia Record No. 49871, "Americanism" by Franklin D. Roosevelt.
8. Columbia Record No. 49864, "Safeguard America" by Mrs. Corinne Roosevelt-Robinson.
9. Columbia Record No. 77666, "Loyalty" by James W. Gerard.
10. Columbia Record No. 49881, "The World War" by James M. Cox.
11. Columbia Record No. 49706, "Revise Taxes" by Wm. G. McAdoo.

In order to make an adequate description of pitch-patterns within single syllables, 81 syllables were selected from the recorded speech of E. H. Sothern, Julia Marlowe, Mrs. Roosevelt-Robinson, Wm. H. Taft, Woodrow Wilson, and Graham McNamee, which to the experimenter seems to constitute a good inclusive sampling of the most general pitch-patterns heard in

ordinary American speech. Each of the thirteen *O*s was asked to describe the pitch-pattern of each of these syllables. To supplement these observations, three *O*s made studies of one hundred additional selected syllables from the speeches of Franklin D. Roosevelt, Rabbi Wise, James W. Gerard, Wm. McAdoo, James Cox, Graham McNamee, and Mrs. Roosevelt-Robinson. Additional descriptive reports were made available in the study of syllables in connected discourse reported in the following paragraph, making a total of practically 3000 descriptive reports of perception.

In the study of tonal movement in connected discourse, three *O*s were used for the first 100 syllables in Shylock's speech in the "Merchant of Venice," and the first 100 syllables in "Immortality" by Bryan. One *O* was used for the second 100 syllables in "Immortality," and another for the first 100 syllables in "Americanism" by F. D. Roosevelt.

*Trained observers with good hearing.* Fourteen *O*s, five women and nine men, were used. All the *O*s ranked high in tests of auditory acuity as tested by the Iowa pitch range audiometer (17) and the Western Electric audiometer No. 2-A; in Seashore tests of pitch, intensity, time and tonal memory (14); in tests of vocomotor adjustment involving ability to reproduce a key tone, ability in singing intervals, and least producible pitch change upward and downward from a key note.[4] (10). All *O*s had a large amount of training in audition, most of them being experienced musicians as well as trained in observation of auditory phenomena. None of the *O*s, with one exception, had any knowledge of tonal movement in speech or had ever considered any aspects of speech melody. To all of them the particular nature of the experimentation was novel and unique. Even at the conclusion of the observations, the 13 *O*s did not know the purpose of the study other than the instructions which were given in observation. There were no attitudinal sets which might have militated against the freest and most naïve analysis and report.

*Objective statements of observers' reports.* The reed organ was taken as an instrument in terms of which pitch perception

[4] I am indebted to Dr. H. M. Williams for assistance in giving these vocomotor tests.

could be described.[5] It was easily adjusted throughout the range of speech tones, was familiar to all *O*s, introduced no great difficulties in comparing tones, possessed a known calibration, and was as fine an instrument as the requirements imposed since interpolations of fourths of a semitone could readily be made by *O*s. But even such interpolations were too fine for a majority of syllables. Tone variators capable of adjustment to single vibrations or less were discarded as being too fine. Thus, through reporting pitch perceived in terms of the scale of the organ, comparisons could readily be made among *O*s.

*Procedure in observations.* Prior to each observational period, the speed of rotation of the phonographic turntable was checked and adjusted so as to insure the same reproduction for all *O*s.

The method followed by Daniel Jones of London University was used. *O* was seated at the reed organ with the phonograph close to his preferred ear. Fibre or soft tone needles were used throughout. *E* placed the tone-arm of the phonograph as near as possible to the desired syllable and removed it immediately after the syllable had been completely reproduced and before the next succeeding syllable had sounded, thus giving *O* an opportunity to retain the impression of the one syllable last heard. Instructions were given as follows:

"I will reproduce a number of speech syllables for you to which you are to listen. I will indicate the syllable to which you are to direct your attention and the syllables or words which precede it. The tone-arm of the phonograph will be removed when the designated syllable has been reproduced so that you can retain the impression of this syllable. Attend only to the pitch and report the pitch in terms of the scale of the organ. It may be that you can not allocate the pitch-pattern of a syllable to exact notes on the organ. In this event you will report the pitch in terms of fractional interpolations of semitones. Be certain, however, that you report *everything* that you hear so far as pitch is concerned!"

Before permanent records were taken of the reports of the *O*s preliminary training series were given in which at three different

[5] The organ tone of all available standard instruments seems most similar in character to the human voice and therefore permits of a maximum of accuracy in reporting tones of speech. *Miles* (10) found that the highest accuracy in reproducing standard tones was obtained from tones of organ pipes. Arguing conversely, the greatest facility in reporting perceived tones of the voice should accrue from the use of organ tones.

observational periods, the same syllables were given in order to ascertain the degree to which *O* could attend with consistency. Although one of the purposes of the experiment was to discover the consistency of reports as a measure of definiteness of the pitch of syllables, a degree of self-consistency was requisite to effective observational work. Training consisted in observations for three weeks of syllables not used in the permanent record. Each *O* was permitted to make naïve reports or descriptions without suggestions from *E*. This served to orientate *O* into the nature of the observational tasks and to point out through self discovery the complexity of the pitch-patterns heard and the necessity for careful attention in order to give a faithful description of the entire pattern perceived.

All periods of observation were reduced to a single half-hour period a day which was found to be the most favorable for all *O*s.

Since the purpose was not to get a measure of discrimination, each syllable was repeated as often as *O* desired and until he was fairly confident of his report. From the reports of *O*s, the following represents a typical example of the method used in reporting pitch-patterns:

"In the beginning, I get a general idea of the pitch-pattern. Then it is mainly a search for the dominant tone of the syllable and to locate it on the organ. The easy syllables I can identify at once from my memory of the pitch, without humming. I can neglect the meaning of the syllable entirely and attend only to pitch. There might be a slight kinæsthetic adjustment to assist me. I generally say that the pitch is so and so—something like the nature of absolute pitch consciousness. I am generally not over a semitone off when I identify it on the organ. My recognition and allocation is almost immediate.

"The second step is to try out my judgment on the organ and compare it with various notes until I find a place on a note or between notes that is satisfactory. I divide the semitone interval into fourths and make judgments on that basis. Sometimes I can judge eighths or sixteenths when I can not place the dominant pitch at any of the fourth points. This is rare, however. Then I check and verify my report by listening to several repetitions of the syllable. Next, I see whether there is a perceived change of movement in relation to this dominant tone or tones and try to ascertain its beginning, ending, and particular nature of movement, whether swift or slow, smooth or broken. In the more difficult syllables, kinæsthesis is used to stabilize the auditory image of the sound heard. In such a situation, I repeat the syllable heard until my reproduction, mostly subvocal, coincides with that heard. Then I proceed to locate the pitch-pattern on the organ."

All *O*s reported using kinæsthesis or laryngeal adjustments to facilitate perception. With the female *O*s, it was necessary to report all pitches in the octave which most nearly approximated their own register. It was difficult for them to indicate with certainty in which octave the male voices were perceived. *O*s noted tendencies to guard against reporting the extent and nature of laryngeal adjustments rather than the auditory impression of the pitch pattern. After a number of trials laryngeal adjustments were reduced to a minimum. Several *O*s reported that they were able to drop out the laryngeal adjustments entirely, although theoretically this is highly questionable.

The reports of *O*s were reduced to graphs on a specially devised physical scale broken up into semitones by a system of notation which was fairly accurate in representing the reports of the *O*s, so that a graphic representation could be had for comparison among *O*s. Before each such record was made, *O* was asked if it adequately represented his perception. In addition, a verbatim report of a majority of all syllables studied was secured, thus giving both a qualitative and quantitative description.

2. *Reliability of perceptual analysis.* Consistency among good *O*s was secured by correlating the reports of the 13 *O*s for the 81 selected syllables, and the reports of the three *O*s for each of the two series of 100 syllables. The consistency of good *O*s in repeated trials of the same material was obtained by correlating the reports of each of three *O*s for successive observations from five to nine months apart for the 100 syllables in " The Merchant of Venice " and the first 100 syllables in " Immortality." Three methods of reporting the possibility and reliability of perceptual analyses were used: (1) statements of *O*s; (2) graphic representation of reports; (3) statistical treatment.

*Statements of Os.* The summarized reports secured from each *O* after the experimentation had been concluded [6] tend to give a critical perceptual description of isolated units of speech and the adequacy of perceptual reports. They are probably of greater

[6] The verbatim statements and general descriptions are on file in the Psychological Laboratory of the University of Iowa. They are too extensive to reproduce here.

value than descriptions given by highly trained phoneticians since the judgments and conclusions are from trained *O*s who had no knowledge of what they were to hear. A typical general report follows:

"The fact that speech tones were describable in terms of positions on a pitch scale was unusually impressive. True, some syllables were more tonal than others and more readily assignable to definite positions, while others were more indefinite although proximate so far as general location on the scale was concerned. I was also impressed with the fact that there were more or less definite intervallic relations between syllables, and even within a particular syllable there was pitch movement from one perceived point to another. With some syllables, these points of reference were more specific than with others. I have wondered as to the meaning factor and differences in the size of the intervallic movement employed within one syllable as for example in an interrogatory syllable. It seemed as though a majority of these syllables studied were located at a single pitch or were reported as pitch points. And in many cases there seemed to be a peculiar character to them which I was not able to describe although I could not analyze out any other tones or any tonal changes. It can well be said that speech syllables are pitch-complexes of a peculiar type and for the most part are not simple."

*Graphic representation.* The following figures represent the

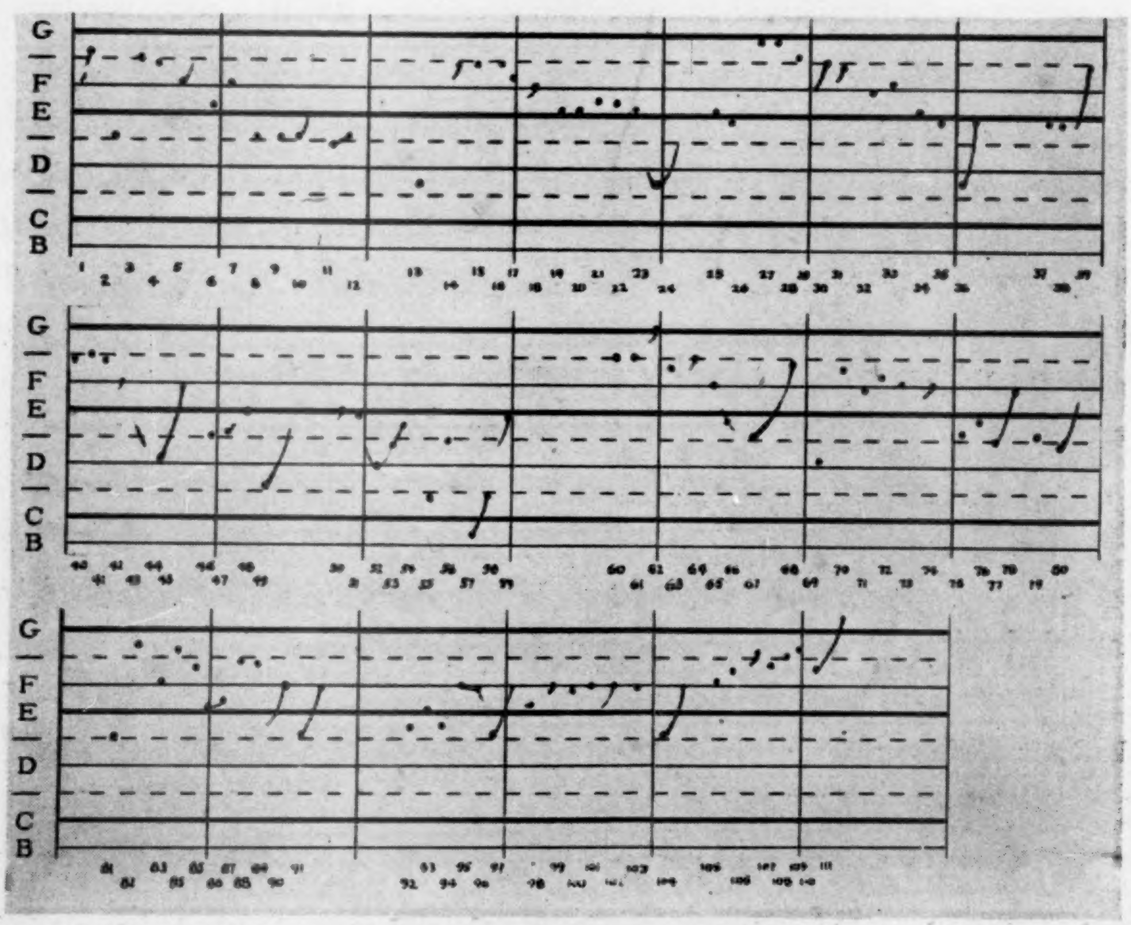


FIG. 1. Graphic representation of the perceptual analysis of 111 consecutive syllables in "Immortality" as reported by B.

perception of 100 consecutive syllables in Bryan's speech "Immortality" as reported by three different *O*s. The scale is one devised by *Metfessel* (9) and was used because of its convenience. No consideration has been given to the factor of duration, the pitch patterns having been plotted in succession without regard to time.

Heavily inked places indicate dominance of pitch. Single black dots indicate that a single pitch was heard. Unbroken lines represent a perceived pitch change in the direction and of the extent as indicated. Broken lines indicate the uncertain perception of pitch change. Thus for example in syllable 1 of Fig. 1, there is an uncertain sweep up to a dominant pitch slightly sharp of F♯. In syllable 104 of Fig. 1, there is a perceived change of pitch from one definite lower pitch to a higher one, the lower one of which is more dominant in consciousness than the upper. There is heard in this case, an intervallic transition within the same syllable of a second.

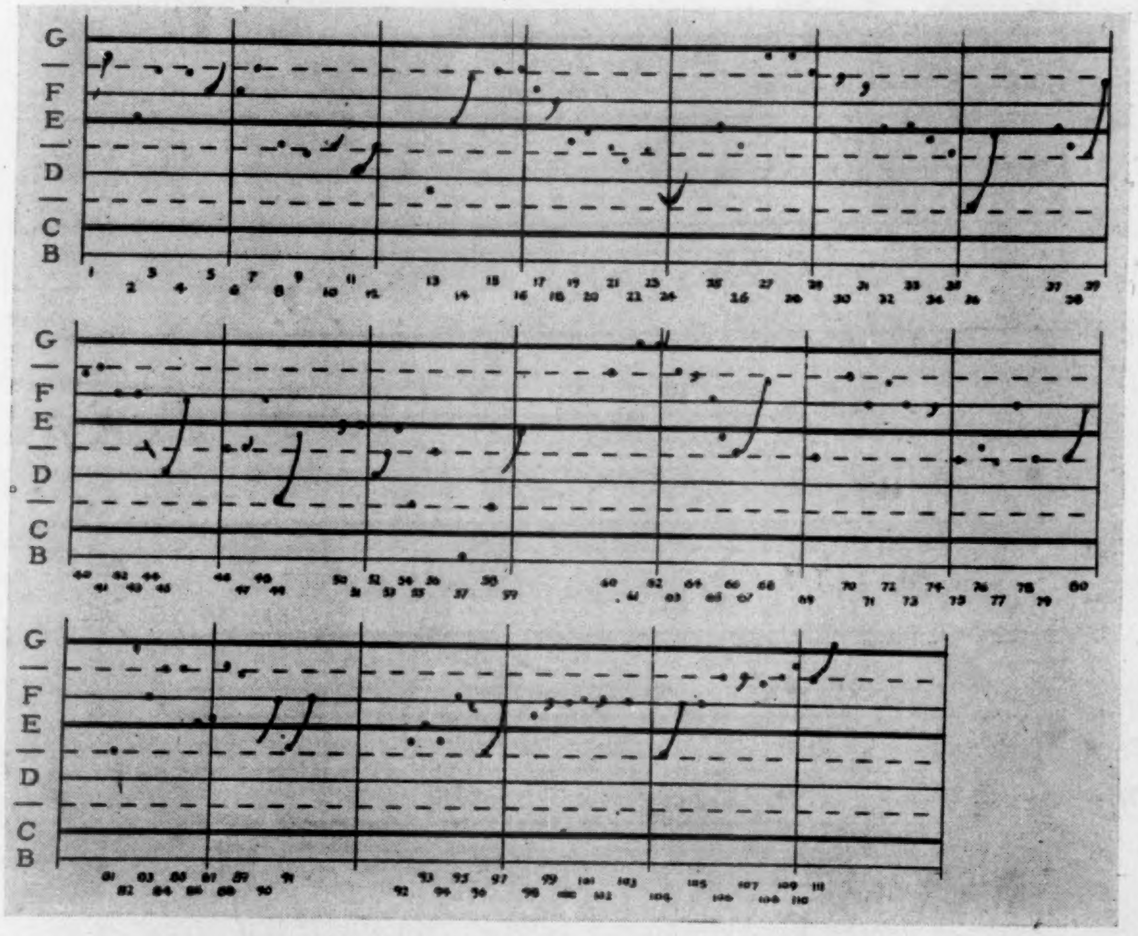


Fig. 2. Graphic representation of the perceptual analysis of 111 consecutive syllables in "Immortality" as reported by G.

The numbers under the scale refer to syllables as follows:

1. if
2. the
3. fa-
4. ther
5. deigns
6. to
7. touch
8. with
9. di-
10. vine
11. pow-
12. er
13. the
14. cold
15. and
16. pulse-
17. less
18. heart
19. of
20. the
21. bur-
22. ied
23. a-
24. corn
25. and
26. to
27. make
28. it
29. to
30. burst
31. forth
32. from
33. its
34. pri-
35. son
36. walls
37. will
38. he
39. leave
40. ne-
41. glec-
42. ted
43. in
44. the
45. earth
46. the
47. soul
48. of
49. man
50. made
51. in
52. the
53. im-
54. age
55. of
56. his
57. cre-
58. a-
59. tor
60. if
61. he
62. stoops
63. to
64. give
65. to
66. the
67. rose-
68. bush
69. whose
70. with-
71. ered
72. blos-
73. soms
74. float
75. up-
76. on
77. the
78. aut-
79. umn
80. breeze
81. the
82. sweet
83. as-
84. su-
85. rance
86. of
87. a-
88. no-
89. ther
90. spring-
91. time
92. will
93. he
94. re-
95. fuse
96. the
97. words
98. of
99. hope
100. to
101. the
102. sons
103. of
104. men
105. when
106. the
107. frosts
108. of
109. win-
110. ter
111. come

The graphic record of these 111 syllables is representative of the graphic agreement of all the material studied, even in the case of syllables that were more complex in their movement.

*Statistical treatment.* Since all reports were given in terms of a pitch scale, quantitative treatment was available. Two methods were used: (1) ascertaining the consistency in the perception of dominant pitch, since all speech syllables, with very few exceptions, were perceived at one or more dominant places upon the scale; (2) ascertaining the agreement in inflectional range. Methods of consistency consisted in the derivation of correlations (product-moment method) using semitones as class intervals, each semitone being taken as the midpoint of its class interval. In deriving the *r*'s for inflectional range, the total distance of pitch movement was taken as a basis of comparison. For example, in a complex pattern in which the pitch began at C, slid up to E, and then back to D, the total range of pitch change or inflection was six semitones. It is true that the quantitative

method has a number of shortcomings. It can not make precise comparison of complete pitch-patterns nor of the qualitative differences heard. Yet it is acceptable with the previous two methods used as supplements to it.

*A. Consistency among observers.* (1) Among 13 *O*s for 81 selected isolated syllables. Observer A, who was known to have the highest scores on the auditory and vocomotor tests,[7] was

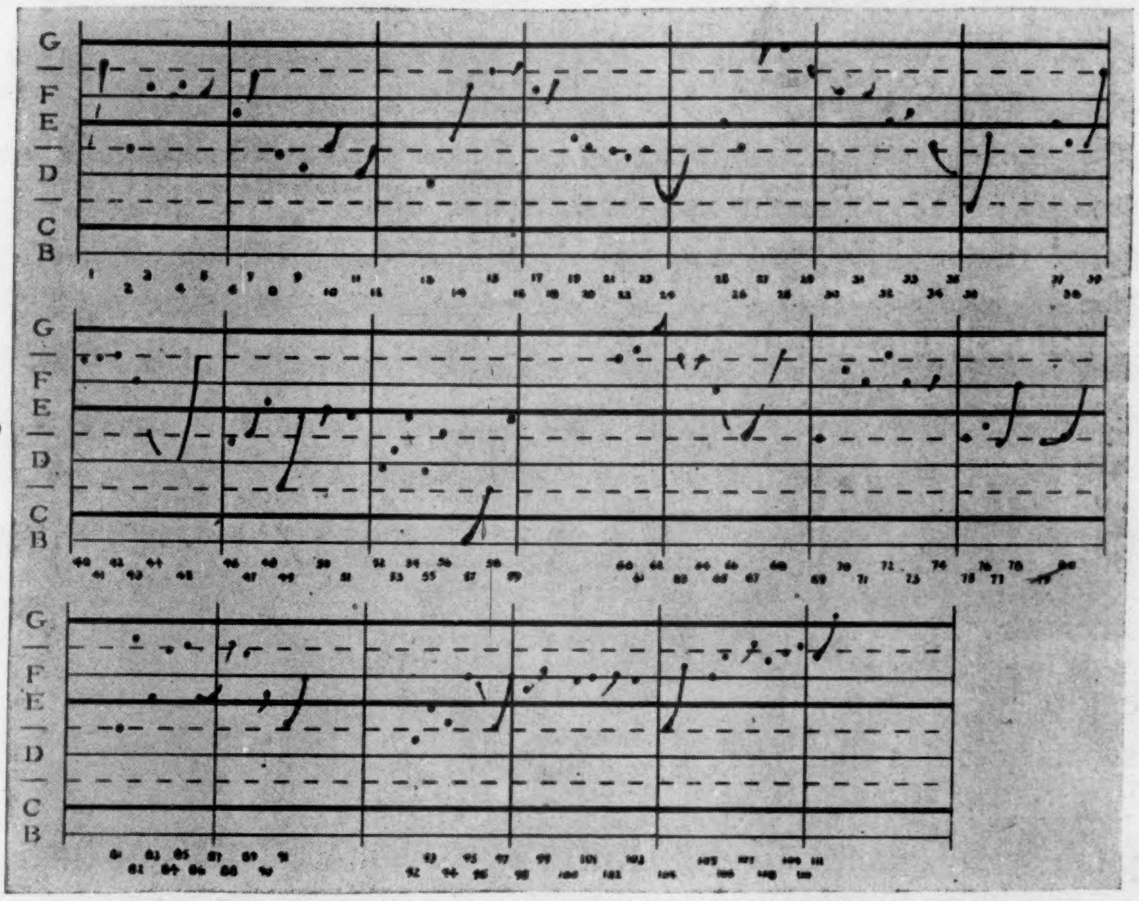

FIG. 3. Graphic representation of the perceptual analysis of 111 consecutive syllables in "Immortality" reported by N.

taken as a standard. His reports were correlated with each of the other twelve *O*s. This was believed to be a justifiable procedure since *O* A had an exceptionally high self-consistency and was known to have an exceptional ear.

Although these correlations are derived with class intervals of semitones, they have greater significance when consideration is

[7] Rank on Seashore Tests of Musical Talent of 99 in Sense of Pitch, 100 in Sense of Intensity, 95 in Sense of Time, 97 in Musical Memory; average Hearing Loss of -9 on the Western Electric Audiometer; Constant Error in Singing Key, .2 d.v.

TABLE I. *Correlations of 12 Os with Observer A in dominantly perceived pitch*

| Observer | r | P.E. |
|---|---|---|
| B | .97 | .005 |
| C | .96 | .006 |
| D | .96 | .005 |
| E | .98 | .002 |
| F | .95 | .008 |
| G | .98 | .003 |
| H | .97 | .004 |
| I | .97 | .004 |
| J | .91 | .015 |
| K | .94 | .008 |
| L | .91 | .012 |
| M | .98 | .003 |

given to the duration of the syllables perceived and the distribution of perceived pitch among them. The duration of the 81 syllables according to physical measurements as described in a succeeding chapter was:

| | |
|---|---|
| Mean | .24 seconds |
| Median | .15 |
| Range | .04 — .75 |
| S. D. | .18 |

The average distribution of dominantly perceived pitch among those syllables was:

| | |
|---|---|
| Mean | $F\sharp_1$ (183 d. v.)[8] |
| Range | $E_2$-$A\sharp$ (31 semitones) |
| S. D. | 7.11 semitones |

The median correlation is .96. Although only 81 items or syllables were used, it is reasonable to assume that through doubling the number, the reliability would not be less since these 81 syllables were empirically selected on the basis of representativeness of all the pitch patterns heard, and inclusion of the most complex and difficult to judge. Applying Brown's formula, $r_x = \dfrac{Nr}{1 + (N - 1)\,r}$, the median correlation of the twelve *O*s with *O* A, with 162 syllables instead of 81, would be .98, tripling would give .99.

The correlations of each of the twelve *O*s with *O* A show greater disparity in inflectional range.

[8] Middle C (256 d.v.) is represented C; the upper octave as $C^1$, and the lower octave as $C_1$, *etc.*

TABLE II. *Correlations of 12 Os with Observer A in inflectional range*

| Observer | r | P.E. |
|---|---|---|
| B | .92 | .012 |
| C | .78 | .030 |
| D | .90 | .015 |
| E | .71 | .038 |
| F | .85 | .021 |
| G | .91 | .013 |
| H | .86 | .019 |
| I | .70 | .038 |
| J | .85 | .020 |
| K | .87 | .018 |
| L | .93 | .010 |
| M | .95 | .008 |

Indirectly these correlations give a general statement of pattern agreement. The relatively high correlations for inflectional range are the result of the tendency to perceive syllables as unipitch[9] rather than a complex pitch-patterns as shown by the following average distribution of inflectional range:

| | |
|---|---|
| Mean | 1.8 semitones |
| Range | 9—16 |
| Median | 0 |
| S. D. | 3.8 |

(2) *Among 3 Os for the 1st 100 syllables of "Immortality."* Correlations for this group indicate the same high agreement in reporting the perception of dominant pitch.

TABLE III. *Correlations among 3 Os in dominantly perceived pitch*

| | r | P.E. |
|---|---|---|
| *O* B : *O* G | .94 | .008 |
| *O* B : *O* N | .96 | .006 |
| *O* G : *O* N | .96 | .005 |

Again the factor of duration as physically calculated makes these correlations of greater significance, although the class intervals are relatively large. The average duration is:

| | |
|---|---|
| Mean | .17 seconds |
| Median | .14 |
| Range | .04 — .57 |
| S. D. | .09 |

The dominant pitch of these 100 syllables has a much smaller spread than the 81 above reported:

| | |
|---|---|
| Mean | D♯ (154 d. v.) |
| Range | $D_2$ — $G_1$ (17 semitones) |
| S. D. | 3.15 semitones |

9 The term "unipitch" is used throughout to denote that a syllable is perceived as a single unchanging pitch.

Another method of showing relationship is by calculating the actual differences in the reports of *O*s. This permits of treating each report without throwing it in a class interval and is the most exact statement of differences.

TABLE IV. *Actual differences in reports of dominant pitch among 3 Os in terms of semitones*

| | Mean | S. D. |
|---|---|---|
| *O* B : *O* G | .56 ± .04 | .64 |
| *O* B : *O* N | .49 ± .04 | .65 |
| *O* G : *O* N | .47 ± .04 | .64 |

The correlations for inflectional range are relatively high among those three *O*s.

TABLE V. *Correlations among 3 Os in inflectional range*

| | r | P.E. |
|---|---|---|
| *O* B : *O* G | .95 | .006 |
| *O* B : *O* N | .85 | .020 |
| *O* G : *O* N | .84 | .020 |

These correlations result largely from the fact of the perception of unipitch syllables in the majority of cases. The average distribution of inflectional range was:

| | |
|---|---|
| Mean | 0 semitones |
| Median | 0 |
| Range | 9 |
| S. D. | 1.46 |

(3) *Among 3 Os for 100 syllables from "The Merchant of Venice."*

TABLE VI. *Correlations among 3 Os in dominantly perceived pitch*

| | r | P.E. |
|---|---|---|
| *O* B : *O* G | .96 | .005 |
| *O* B : *O* N | .95 | .005 |
| *O* G : *O* N | .97 | .004 |

These correlations, also, may better be interpreted in the light of the duration and distribution of perceived pitch of these syllables. The time values as physically derived were:

| | |
|---|---|
| Mean | .26 seconds |
| Median | .19 |
| Range | .02 — 1.12 |
| S. D. | .02 |

The average distribution of dominantly perceived pitch among these 100 syllables was:

| | |
|---|---|
| Mean | A♯ (228 d.v.) |
| Range | $D\sharp_1$–F♯ (15 semitones) |
| S. D. | 3.37 semitones |

TABLE VII. *Correlations among 3 Os in inflectional range*

| | r | P.E. |
|---|---|---|
| *O* B : *O* G | .89 | .013 |
| *O* B : *O* N | .82 | .022 |
| *O* G : *O* N | .85 | .020 |

The average distribution of inflectional range was:

| | |
|---|---|
| Mean | 1.5 semitones |
| Median | 0 |
| Range | 0—16 |
| S. D. | 4.2 |

*B. Consistency of the same observer for repeated trials.* The results of a repetition after a period of from five to nine months by the same *O* show a situation similar to the agreement among *O*s. The agreement in inflectional range is slightly higher for the 100 syllables used in "Immortality" than might have been the case had syllables been used from which so large a majority would not have been perceived as unipitch.

(1) *Among 3 Os for 1st 100 syllables of "Immortality."*

TABLE VIII. *Correlations of 3 Os in dominantly perceived pitch in repeated trials*

| | r | P.E. |
|---|---|---|
| *O* B : *O* B | .95 | .006 |
| *O* G : *O* G | .95 | .006 |
| *O* N : *O* N | .94 | .007 |

TABLE IX. *Actual differences in reports of 3 Os in dominantly perceived pitch in repeated trials in terms of semitones*

| | Mean | S. D. |
|---|---|---|
| *O* B : *O* B | .60 | .65 |
| *O* G : *O* G | .55 | .62 |
| *O* N : *O* N | .61 | .64 |

On the basis of Table VIII and Table IX, for the 100 syllables taken as a sampling, the correlations for *O*s in repeated trials of the same material is not less than the correlations among *O*s for the same material. So far as actual differences are concerned, the S. D.'s are approximately the same among the three *O*s as for each *O* in repeated trials of the same material.

TABLE X. *Correlations of 3 Os in inflectional range in repeated trials*

| | r | P.E. |
|---|---|---|
| *O* B : *O* B | .91 | .012 |
| *O* G : *O* G | .92 | .010 |
| *O* N : *O* N | .87 | .016 |

The agreement in this case is rather high, as suggested previously. Since the majority of syllables in this sampling were perceived as unipitch, there should be a higher agreement than would be the case in more complexly perceived pitch-patterns.

(2) *Among 3 Os for 100 syllables of "The Merchant of Venice."*

TABLE XI. *Correlations of 3 Os in dominantly perceived pitch in repeated trials*

| | r | P.E. |
|---|---|---|
| *O* B : *O* B | .95 | .006 |
| *O* G : *O* G | .94 | .008 |
| *O* N : *O* N | .93 | .010 |

TABLE XII. *Correlations of 3 Os in inflectional range in repeated trials*

| | r | P.E. |
|---|---|---|
| *O* B : *O* B | .89 | .013 |
| *O* G : *O* G | .81 | .023 |
| *O* N : *O* N | .78 | .027 |

The agreement in dominant pitch is similar to that reported in the previous tables. The agreement in inflectional range is considerably less than that for dominant pitch since the patterns perceived were much more complex. In "The Merchant of Venice," the speech syllables have a larger range of inflection in general than the average. As the statements of the *O*s suggest, the total complex patterns of many of these syllables can not be reported with certainty. Yet the reliability, on the whole, is sufficiently high for the purposes of perceptual studies.

*Summary of reliability of perceptual analysis.* With attention to their task, observers can make analytical reports of perceived pitch-patterns with a high degree of consistency as statements of observers, graphic comparison, and statistical treatment have revealed. The perceptual approach to the study of pitch-patterns in speech as employed in this study is highly objective and yields descriptions which are highly reliable.

3. *Perceived pitch-patterns in single syllables.* The reports of *O*s with reference to the perception of pitch show that there is vocomotor facilitation under analytical conditions, especially in the complex patterns where the pitch changes considerably and quickly. Kinæsthesis plays an important rôle as shown by the fact that all women *O*s perceived the pitch in their own register

regardless of the octave in which the spoken sounds were located. The reports of *O*s with reference to the methods used in reporting the pitch-patterns likewise showed a uniform tendency to use kinæsthesis, particularly in the more difficult patterns.

Although no special or extensive investigation was conducted on the relationship of the speech habits of *O*s to their perception of speech sounds, there is a tentative corroboration of Peter's finding that *O*s tended to hear according to their own inflectional habits. In the case of one *O*, who was not used in the body of this study, and whose speech was extremely monotonous, as indicated by an objective check, the perceptual reports of connected discourse showed little variation in pitch, although all other *O*s who possessed good inflectional variation reported very wide changes.

*Classification of pitch-patterns perceived.* From the three thousand perceptual reports of speech, it is not possible to make conclusions other than categorical descriptions. From the standpoint of the hearer, there are individual differences in the total patterns heard from the same physical pattern acting as a stimulus, but all of these can not be presented. The patterns here presented are those reported under analytical conditions by *O*s with good hearing. Reference is made to graphic representations of these various patterns in Plates III, IV, and V.

(A) *Single pitch syllables.* A plurality of all the syllables analyzed were heard as unipitch, although their character varied considerably. Syllables of brief duration had a tendency to be perceived at one pitch. Connectives such as " and," " but," " if," and the like were commonly found in this class. Some syllables of much longer duration were also unipitch. For example, " good old " in Wm. H. Taft's speech " Who are the People " (see Plate V, Fig. 43) was heard as two definite pitches, the latter heard as extremely tonal. All those syllables schematically represented by single dots in Figs. 1, 2, 3 (pp. 117 to 120) were in this category.

(B) *Perceived pure glide without a terminal pitch.* A very few syllables were perceived as short slides at some approximate position on a pitch scale, with no point of dominance in the entire

slide. The falling slide at the end of the melodic unit and transitional syllables between a low and a higher pitch evince this pattern. The direction of pitch movement is definitely recognized, but the extent of the slide and its termination are uncertain. Fig. 1, No. 44, represents such a pattern. Bryan's speech contains several of them.

(C) *Perceived tonal movement toward or away from a single dominant pitch or both.* Six types of patterns are included in this category: (a) movement up toward a dominant pitch, (b) down from a dominant pitch, (c) from a dominant pitch upwards, (d) down to a dominant pitch, (e) up toward and down from a dominant pitch, and (f) down to and up from a dominant pitch. For example, the word one in " Immortality " was described by one *O* as follows:

" Upon first hearing this syllable, it seemed like a unipitch; but there was a peculiar quality to it which made one feel as though something else were present. Upon closer analysis a very swift slide upward from some beginning point which was not definite took place, terminating at F."

(D) *Intervallic movement within a vowel diphthong.* There is a marked tendency to hear vowel diphthongs as in " out " (aut), " eyes " (aɪz), " time " (taɪm), *etc.*, as patterns with two definite pitches bearing an interval relationship. The diphthong consists of two terminal pitches of a rather high degree of definiteness, usually connected by a slide, although in many cases the fact of a slide is not present. In perception one tone is heard which gradually disappears while the second looms up in consciousness. The whole transition is so swift that at times the two terminal tones are heard together for a very brief time. Most generally the interval change is from a lower to a high tone. The following are reports by two *O*s of a typical pitch-pattern of this class and describes the perception of " Christ " from " Immortality."

" The voiceless consonants do not partake of the pitch movement. So far as pitch was concerned, the word was perceived as a unitary pattern and was dominated by the pitches at about $D\sharp_1$ and $F\sharp_1$, the latter being more dominant than the former which might be termed secondary to it. There was a quality of sounding which made it appear as though these two tones were present simultaneously. It was as though $F\sharp_1$ were in the foreground and $D\sharp_1$ in the background. There was a connectedness between these two tones, how-

ever. After several repetitions of the syllable, I became aware of two vowel sounds comprising a diphthong with a quick change of timbre from one to the other. There was also a definite change of pitch from one of these vowels to the other, but this change or tonal movement was not in the foreground. It was only present upon close analysis and attention."

"I perceive two points of reference distinctly as two successive tones with a slide from the lower to the upper pitch. It seemed as though the first constituent vowel of the diphthong was on the lower pitch, the second vowel on the upper pitch. While the upper pitch, the last in the rising slide, contributed the dominant tone in the perception of the complex mass, there was a very clear impression of these two extreme tones coming in quick succession with a positive identification of an upward slide connecting the two. It seemed as though both tones sounded together for an instant."

(E) *Perception of intervallic movement within a single vowel, forming a pure pitch diphthong.* Just as in the former case, there is a change from one definitely perceived pitch to another which may be a gradual transition of a slide or a sudden transition without a perceived slide. In many cases the pitch diphthong is heard as though the vowel in which the pitch diphthong appears were composed of two portions. The fact of a definitely perceived interval between these two pitches is reported; the two pitches comprising the diphthong stand in an intervallic relationship such that a melodic pattern of its own is heard. These patterns have a definite beginning and ending, the termination being abrupt rather than gradual.

(1) "Until" (Plate IV, Fig. 18) from Mrs. Roosevelt-Robinson.

"I hear two pitches, the one at F♯, the other an octave below. I hear the upper one first and then the lower pitch and infer that there has been a transition, although I did not hear the movement or change of pitch as such. One tone came in suddenly upon the other. The two pitches were perceived with a definite intervallic relationship of an octave and were unvarying in pitch while they lasted."

(2) "Dead"

"Isn't that odd! He hits a minor third. The pitch moves from $C_1$ to $D\sharp_1$, a very definite, clear-cut slide, with two points of reference dominant in consciousness, namely the beginning and the end. The slide was an inherent part of the complex, however. It strikes me very odd that he uses a minor third for the expression of this particular word, for in music that interval is generally very mournful."

(F) *Perception of intervallic movement between a vowel and a semivowel (w, l, m, n, η) or vice versa.*[10] From the standpoint

[10] A precise study of the participation of consonants in perceived pitch-patterns other than those described is exceedingly difficult at present because of the deficiencies in recording and reproducing them. Physical approaches likewise face these same difficulties.

of their contribution to the dominant melody or pitch-pattern of a syllable, certain sounds sometimes classified as consonants may be formed so as to act in the same capacity as sounds ordinarily classed as vowels. When this occurs, there is probably a minimum of obstruction within the buccal cavity and pharynx, and a longer duration or lengthening of the sounds themselves. Under such conditions, the sounds are really vowels according to their participation in dominant melody. In a great many cases, these semivowels have tones or dominant pitches of their own which differ from those of the vowels, and in the transition from these sounds to vowel sounds, intervallic transitions occur. Such perceived patterns are similar in pitch to those of the previous category.

(G) *Perception of pitch triphthongs.* Within a single syllable three pitches with intervallic relationships among them may be heard. These three definite and dominantly perceived pitches may be found within a single vowel, or in transitions from a vowel to a semivowel or *vice versa.* They are similar in character to the pitch diphthongs except that the melodic pattern is made more complex by the addition of the third member. Examples are found in " name " (Plate V, Fig. 35) from Shylock's speech in " The Merchant of Venice "; and in " war " (Plate IV, Fig. 21) from Mrs. Roosevelt-Robinson. In the former, the first pitch was in the vowel " e," while the two succeeding ones were in the semivowel " m " which followed. In the latter word, the first pitch was in the semivowel " w," while the last two were in the vowel " ɔ:".

(H) *Perception of intervallic movement between two syllables of a word where there is continuity of tone.* Although the mode seems to be a change from one more or less definite point to another in all pitch changes whether within a single syllable or from syllable to syllable, there are perceived intervallic relationships between two syllables in the same word which have no interruption of tone. In many bisyllabic words in which the two syllables are connected by a voiced consonant participating in the tonal pattern, there is a perceived glide between two rather definite points acting as a sort of legato transition. Sometimes the pitch movement is not perceived as such, and is only inferred.

(1) "During" (Plate IV, Fig. 24) from Wm. H. Taft.

"Each syllable is perceived as a unitary pitch, the first at $D_1$, the second at $F\sharp_1$. There is a decided and abrupt change of pitch from syllable to syllable, although there seems to be no break in between; there is a blending of one pitch with the other. The second is cut off so quickly that I didn't have to wonder whether it started lower or ended higher. It didn't. It was just a unipitch."

(2) "Hindered" from Shylock's speech in "The Merchant of Venice."

"F♯ is dominant for the first syllable and $\dot{C}\sharp_1$ for the second, these two pitches constituting points of reference. There is a continuous movement from about F or slightly below up to F♯ and moving so rapidly from F♯ downward to $G\sharp_1$ that it wasn't really apprehended as such. There seemed, however, to be no break, and when the upper tone faded away and the lower one loomed up, the fact of a slide was inferred."

(I) *Perception of complex patterns.* Although the mode in perception is to hear more or less definite points of reference in the pitch movements within syllables and from syllable to syllable, there are certain patterns which have no definite intervallic relationship or which do not proceed from one point of reference to another. This is rare, however. In such patterns there is the perception of complex glides in which certain portions are more dominant than others. They may take any form of movement.

"Cooled" (Plate V, Fig. 45) from Shylock's speech in "The Merchant of Venice."

"There were three points of reference which were not perceived as tonal terminal points. They were merely boundary points of the complex pattern of pitch movement and were located at D♯, C, and D♯. There was constantly changing pitch moving from D♯ down to C and back to D♯ in a sort of portamento movement, thus giving a unique melodic pattern. The outstanding character of this syllable was the continual movement."

*Perception of tonality, smoothness, definiteness of pitch; of noisiness, roughness, and indefiniteness.* Although the particular patterns of pitch have been described categorically, there are vast qualitative differences within a given pattern. Some syllables are perceived with a high degree of definiteness in pitch and can be reported with certainty while others have a general location on a pitch scale but possess a quality which makes the pitch elusive to identify. Sounds of weak stress, particularly, are found in the latter category. Still further, some syllables are relatively free from noise qualities and are heard as smooth, broad, full, steady,

while others are extremely noisy and possess a minimum of pitch. Especially is this latter true of gutturals. The best example of tonality in speech is found in "good *old*" from the speech of Wm. H. Taft (see Fig. 36, Plate V) described by *O* as follows:

> "This word has a very distinct and definite pitch which is a real tone. It is so full and rich and has a breadth which makes it extremely musical. It is very easy to identify and is different from most of his syllables."

Examples of syllables which were reported as rough, rumbly, noisy, guttural, indefinite are found in the words "disgraced" (Fig. 1, Plate III), and "eyes" (Fig. 4, Plate III), in Shylock's speech.

4. *Perception of speech melody.* The method of perceptual analysis reported here was applied to the pitch factor in connected discourse, taking the recorded speech "Immortality" by Bryan as the subject for study. The *O*s reported that the sequence of pitch-patterns, analyzed in isolation, fairly well represented the melodic flow of speech. It was found that a number of principles of melodic progression were present. Among them were: changes in "key" or dominant pitch, or pitch level, variations in inflectional range, variations in cadences, variations in patterns of movement, recurrences in repetition, melodic balance of patterns of movement, and melodic unity.

5. *Summary.* 1. The method of perceptual analysis of recorded speech as used in the present study has a high degree of consistency as statements of *O*s, graphic agreement, and statistical treatment of results show. The consistency is greater for dominant pitches than for the total pitch-pattern as measured by inflectional range. The average correlation among *O*s in the perception of the same material is .95 for dominantly perceived pitch and .86 for inflectional range; and for *O*s in repeated analyses of the same material, .94 to .95 for dominantly perceived pitch and .86 for inflectional range.

2. Perceptual pitch-patterns in speech syllables have been categorically described as follows:

(1) Single pitch, which characterizes a plurality of syllables.

(2) Perceived pure glide without a terminal pitch. Only a very few syllables evince such a general pattern.

(3) Perceived tonal movement toward or away from a single dominant pitch, or both:

(a) Movement up toward a dominant pitch.
(b) Movement down toward a dominant pitch.
(c) Movement upwards from a dominant pitch.
(d) Movement downwards from a dominant pitch.
(e) Movement up toward and down from a dominant pitch.
(f) Movement down to and up from a dominant pitch.

(4) Intervallic movement within a vowel diphthong.

(5) Intervallic movement within a single vowel constituting a pure pitch diphthong.

(6) Intervallic movement between a vowel and a semivowel or vice versa.

(7) Perception of pitch triphthongs or intervallic movement among three points of dominance.

(8) Intervallic movement between two syllables of a word where there is continuity of tone.

(9) Complex patterns of various kinds.

3. Some syllables are perceived as tonal, smooth, and definite, while others are perceived as noisy, rough, and indefinite.

4. Although the total pattern of pitch within a single syllable varies considerably, most syllables possess one and sometimes two or three points of dominance.

## II. Physical Frequency Patterns

1. *Procedure.* The physical approach gives a more precise statement of the nature of the speech sounds which are produced and which act as stimuli since it catches the fine as well as gross movements which the ear does not hear. In addition, it gives an indirect physiological approach to the function of the vocal musculature.

*Apparatus.* The method of phonophotography described by *Metfessel* (8) was used both for recording from phonograph records and in direct photography of the speaking voice.

*Method of reading.* The wave-length method of reading films under a reading lens offering a magnification of 2 diam. was used in all cases. A small pair of finely pointed dividers were used to locate the distance between critical points of consecutive waves.

The dividers were then transferred to a millimeter scale cut in glass and also set under the reading lens, and the distance between points read in terms of millimeters, estimates of twentieths being made.

*Errors in reading.* Errors in reading and errors in recording are the two main sources of error. There are three sources of error in reading wave-lengths; namely, (1) in locating wave-groups which constitute a single complex wave; (2) in locating the critical point of recurrence, and (3) in estimating fractions of a millimeter.

(1) *Errors in identifying complex waves. Scripture* (**13**) has pointed out that a complex wave consists of a series of waves, a wave-group rather than a single wave, and that the limits of such a wave-group are recognizable by the recurrence of some characteristic feature. In sustained tones, as in singing, the difficulty of locating the limits of complex waves is reduced to a minimum. In the records of speech, this difficulty is increased to a maximum, where within the progress of a single vowel or voiced consonant, alterations in wave-form constantly take place; where wave-groups consist of two or more waves which appear to the reader as essentially the same; in swift transitions at the beginning of a syllable, between a voiced consonant and a vowel, or in the progress of speech sounds where no recurrence of the same wave-group appears at all; and finally, where there is a gradual transposition of a wave-group to form a new single wave, or where a single wave breaks up into exactly recurring smaller waves.

(2) *Errors in locating the critical point of recurrence.* Two sources are present here. Differences in breath-pressure and amplitude of successive waves distort the readings of distances between the absolute critical points of waves. This may be minimized by drawing an imaginary vertical line from a given critical point and placing one point of the dividers upon it at a height equal to the critical point of the following wave.[11] But

[11] *Simon* (**15**) made use of a base-line drawn through the middle of a wave, the intersection of the wave with the base-line being taken as a critical point of reference. He suggested the erection of new axes to bisect waves to overcome the error which might otherwise result from differences in breath-pressure.

even with this method there may be cause of error, since in speech where continual changes may take place in the form of consecutive waves, there may often be a shifting of a characteristic peak in relation to other portions of the wave (**13**, p. 65). Errors are likewise introduced in waves which have no sharply defined points of reference, such as in waves with rounded or flattened troughs or crests. This latter may be minimized by increasing the amplitude of a wave during the recording and giving careful attention to the optical lever.

In the present study, after six months of intense practice in reading film, a test of consistency of the reader was made with a film of a female voice bearing a record of the word "hello." The average length of waves was 6.27 mm., the shortest average wave length of any film used. The average difference between two readings six months apart was .08 mm. and the average difference between the method of reading employed throughout the study and reading under a reading microscope graduated to .001 mm. was .07 mm. Consistency with another good reader was found to be ±.08 mm. These tests indicated that errors in (1) and (2) above account in a large measure for differences, and that a method of reading finer than that used was impractical.

*Errors in recording.* Errors produced by vibrations set up by the driving motor and lateral oscillations of the revolving drum were minimized by fastening the driving motor to a firm support and resting the tripod of the phonelescope upon a stand fastened to a tile wall. As a check against slippage of the silk thread about the axle supporting the mirror in the phonelescope, films of phonographic records were exposed twice. Exact coincidence of waves at every point should result if the same speed of rotation is maintained. As a further check the tone of a tuning fork was photographed at intervals. A regular sine curve should result when the phonelescope is in proper condition and diversions from it is an indication that the instrument is not in good condition.

*Plotting wave-length readings.* In the readings of sounds from phonographic records, a conversion scale was drawn up,

making the transposition from wave-length into statements of frequency convenient. In direct photography the form $f = \frac{L}{1}$ was used, where the *L* was the length of the wave of the 100 d.v. tones used as a time line, *1* was the length of the vocal wave, and *f* was the frequency to be obtained. Each wave of the time-line was read, since the constancy of the driving motor was not assumed. Readings of frequency were plotted on a physical scale identical to that for plotting perception.

*Selection of material for photography.* Over 400 records of the speech of 40 persons were secured and formed the basis for the descriptions subsequently presented. (1) The 81 syllables used in the perceptual studies were photographed and read. Many of these syllables had previously been recorded by *Merry* (6) with his disc-lever apparatus. His readings were made in time-units which introduced an element of smoothing. Furthermore, the time-units themselves were not always precise, due to slippage of paper and belt. The general direction and extent of tonal movement as he reported was found, however, to be fairly accurate. (2) Certain syllables or words from phonographic records which seemed to consist of unique patterns were filmed. (3) Direct photography of words and customary expressions of greeting was used both for frequency-patterns of syllables as well as tonal movement and transitions in a relatively simple type of connected speech.

During the process of reading records and plotting results, pitch periodicities of various types were found, some of which resembled the vibrato as reported by *Schoen* (12), *Kwalwasser* (5), *Herzberg* (3), *Metfessel* (8), *Gray* (2), and *Forchhammer* (1).

A more extensive survey of these periodicities was made. The material for study was obtained by direct photography of the speech of persons who were accustomed to the process of recording and who could speak without the usual excitement which accompanies a novel situation such as having one's voice photo-

graphed; two records of highly dramatic speech (Victor Record No. 74663, "Romeo and Juliet"—Balcony Scene—Part 2, by E. H. Sothern and Julia Marlowe; Victor Record No. 74673, "The Merchant of Venice," by E. H. Sothern and Julia Marlowe); and the recorded radio announcement of the reception to Colonel Charles A. Lindbergh at Washington, D. C. (Victor Record No. 20747-A). This latter record is of especial significance since it represents the refined recording of the speech of an experienced announcer in actual situations calling for a minimum of simulated emotional responses. Parts of this record were photographed where the songs from the crowd, bands, and other sources seemed to be absent; and where, with a score of listeners, highly intense emotional responses resulted.

2. *Gross physical frequency-patterns.* The conclusions of physical descriptions, like those of perception, must be categorical.

(A) *Physical patterns evince tendencies toward definite pitches.* The extent to which there is a definiteness varies with the individual and with a factor of duration.[12] In some instances level pitches are evinced, although there are individual differences with reference to the smoothness of sustained pitches. Note the relative smoothness or levelness in "fail" (Fig. 9, Plate III) with the exception of the break resulting from a shift of position of the articulatory organs to produce the last sound, in "and" (Fig. 17, Plate IV), and in "old" (Fig. 36, Plate V). Greater smoothness is scarcely found in the most rigid of singing tones. More or less incomplete tetanus may result in more or less varying pitch of the tone produced. "Dis" (Fig. 1, Plate III), "is" (Fig. 7, Plate III), "that" (Fig. 5, Plate III), "it" (Fig. 6, Plate III), "out" (Fig. 21, Plate IV), "and" (Fig. 17, Plate IV), "proposes" (Fig. 29, Plate V), each of the syllables in "monopoly" (Fig. 42, Plate V), "but to take" (Fig. 30, Plate V), "old" (Fig. 36, Plate V), and words in Figs. 48, 49, 54, and 56 (Plate VI) are exemplary.

[12] In some records large differences in consecutive wave-form appear, which result in differences in individual wave-lengths. The problem of smoothness of pitch is tied up both with wave-form and wave-length, for the two are inseparable. Complete studies in the future must take both into consideration, particularly in differential studies and problems in æsthetics.

In movements upwards or downwards, particularly with short duration, a level pitch is not maintained; only an approximation to a level pitch results. For example, "graced" (Fig. 1, Plate III), shows an approximation of a definite pitch following the upward slide. The last "do" (Fig. 47, Plate VI) shows a very definite and level pitch at the peak of the circumflex. The "hello" (Fig. 50, Plate VI) is a beautiful illustration in point. The pitch began at $D_1$, slid up to a trifle below A♯, back to $E_1$ and up again to A, with a drop to $F\sharp_1$ at the release. The four levels of pitch connected by glides are apparent. This latter frequency-pattern was from perfectly spontaneous speech without instructions of any kind. Such level pitches are not so apparent in speech which utilizes swifter transitions, as in Fig. 59, Plate VI. The first word in this figure is an "hello" spoken normally by this particular subject. The second "hello" is the pattern resulting from instructions given to execute a perfect fifth in the first two pitches of the syllable after considerable practice. The interval was exceeded as might reasonably be expected when such quick changes are made. But a definite pitch was intended for the upper portion of the circumflex. Between the two patterns there is little difference. In swift changes such as are presented in the graphs cited, it is scarcely possible that level pitches should be maintained, knowing the nature of muscular action. Fig. 23, Plate IV, is the frequency-pattern produced by *O* under instructions to execute a fourth between "con" to "fuse," and an octave from this latter pitch to the lower one. *O* was drilled for a long period until he felt reasonably certain that he had developed a kinæsthetic set for the pattern. The record shows an approximation to a definite pitch in the first syllable, a swoop up to an approximate level pitch, sharp of $F_1$, with a return to a level pitch at $G_2$. Although the pattern as instructed was not executed, there is physical evidence of a tripitch pattern in this word.

There are differences in the levelness of pitches depending upon individual differences in response of the vocal musculature coupled with the factor of duration. For example, Wilson's execution of "proposes as his platform" (Fig. 29, Plate V)

with the exception of the first and fifth syllables, shows only general approximation to a single pitch. Yet the words which follow, as shown on the same plate, show a striking definiteness—"not" (Fig. 39), "to abolish" (Fig. 33), "monopoly" (Fig. 42), "but to take" (Fig. 30). "How do you do" in Fig. 56, Plate VI, shows unusual definiteness of pitch.

(B) *Mode of transition from pitch to pitch.* Where syllables are connected by voiced sounds, or in transitions from pitch to pitch within a single voiced sound, the movement from place to place on a scale of frequency is generally by slides. This is due to the fact that the vocal cords are in constant vibration and that changes in tension necessary for changes in pitch occupy time. Although there is no direct evidence with reference to the phases of shortening and relaxation in the vocal musculature, our argument may be based upon the known action of single muscles (4, p. 27–28). In the vocal musculature where there is a rather complex integrated action of a number of muscles involved in the production of any speech sound as well as in making transitions from one speech sound to another, it is not unreasonable to assume that in striking toward a high or low tone, a curve of contraction or relaxation or both should result, thereby producing slides of various kinds, so long as the vocal cords are in vibration. And it is further reasonable to assume that there will be individual differences in the period of the shortening and relaxation phases as well as differences in the smoothness of the contraction and relaxation integration.

There are large differences in speed of transition as presented in the graphs of Plates III, IV, V, and VI. In terms of semitones, the speed of transition varies from .006 second (Fig. 32, Plate V, in the slide from F♯ to A) to .047 second (Fig. 17, Plate IV, in the slide from C♯ to F♯$_1$), with a mode at about .016 second. Fig. 41, Plate V, represents the word "good" spoken under instructions to make the most rapid transition of a fourth that was possible. After considerable practice, *O* spoke for a record. The speed of transition per semitone was .014 second which is relatively fast when compared to the speed of change ordinarily effected in conversational speech. The excep-

tions to this statement are found in transitions between two vowel sounds in the same syllable where rapid changes of the organs of speech result in pitch changes due to the sudden raising or lowering of the hyoid and indirectly of the thyroid cartilages. Fig. 27 in Plate IV, and Fig. 39 in Plate V are examples in point.

In voiceless sounds there are large breaks in the movement of pitch, although there may be very quick or brief slides into the physically dominant pitch, or a clean attack of a level pitch. In Fig. 18, Plate IV, for example, the slide between the first and second syllables is not present—a slide that would ordinarily be found in the case of a voiced sound connecting the two. But physiologically, there is the same adjustment in the tension of the vocal cords. Fig. 23, Plate IV, shows a transition in pitch that did not begin until the initiation of the second syllable. On the other hand, Figs. 30 and 42, Plate V, show a transition between the second and third syllable separated by a plosive in which a clean attack and maintenance of a level pitch was made on the third syllable. In most instances, then, the slide is an incident in the transition of pitch.

In swift transitions from high to low pitch, syllables evince pure glides, although with sufficient duration, there are more or less definite pitches approximated (see, for example, Fig. 11, Plate III, Figs. 16, 18, 22, 23, and 25 of Plate IV; and Figs. 29 and 31 in Plate V). On the other hand, transitions from low to high evince a greater degree of definiteness in pitch changes. Physiologically, a presumption is created toward greater facility in adjustment during contraction phases than in relaxation phases.

The use of slides and glides both in the attack of pitch and in transition from pitch to pitch in speech is not unlike that in music. For example *Schoen* (**12**) has shown that, in singing, a tone is almost invariably attacked below the pitch intended when the previous tone is lower, the range of the sweep varying with the distance below of the preceding note; that a tone is rarely sustained on the same pitch for an interval of time beyond half a second; that glides are the predominant mode of transition from note to note, *etc., Metfessel's* graphs of "Annie Laurie"

sung by various singers (8) show the glide transitions from note to note both for a portamento and legato where the words sung were not temporarily discontinued by a consonantal break. Even in a new attack at the beginning of a phrase or measure, slides of two to three semitones are present. In a legato transition, where a consonant stop results in a complete break between one tone and the suceeding tone, glides of two and three semitones up to the intended succeeding note are seen.

(C) *Intervallic movement.* Movements from one relatively definite pitch to another definite pitch are often present both in single syllables and in transitions from syllable to syllable. Individual differences and the factor of duration account for differences in the definiteness of such changes.

(1) Within single syllables these definite changes form very definite intervallic movements of various patterns.

I. There is often a pitch diphthong present, or movement from pitch to pitch between two vowels of a vowel diphthong. Fig. 4, Plate III, shows a very quick attack on the first vowel of the diphthong with a relatively long sustained pitch on the second vowel. The attack, in this case, is characteristic of a sudden release in breath-pressure as discussed later. "Always" in Fig. 17, Plate IV, shows a downward intervallic movement in the physical pattern of somewhat more than a semitone. Fig. 27, Plate IV, shows the interval change very nicely, with a very brief duration of the first vowel and a relatively long duration of the second vowel, a semitone higher. Shifts in the position of the tongue may indirectly effect the vertical position of the thyroid through its connection with the hyoid cartilage and thus changes in tension of the vocal cords may result. This, however, is not a complete explanation since records have been found in which the interval change between vowels is as much as four and even five semitones.

II. Intervallic pitch movements take place within a single vowel, thus forming pitch diphthongs. Fig. 13, Plate III; Fig. 23, Plate IV; Fig. 32, Plate V; Figs. 48, 49, 50, 51, 54, and 56, Plate VI, show this tendency in a marked degree. Especially in Fig. 56, "How do you *do*" shows the movement from one definite pitch to another within a single vowel very clearly. The

definiteness of this pattern throughout is a marked contrast to the pattern of the same expression in Fig. 57.

III. Intervallic movement may take place between a semivowel (*l, m, n, y, w,* and *r*) and a vowel or *vice versa.* Figs. 2, and 11, Plate III; Figs. 18, and 21, Plate IV; Figs. 33 and 39, Plate V; and Fig. 58, Plate VI, are examples.

IV. Pitch triphthongs may be formed within single vowels, or between a semivowel and a vowel such as in Fig. 21, Plate IV; Figs. 32 and 35, Plate V; and Fig. 50, Plate VI.

(2) From syllable to syllable there are tendencies to approximate more or less definite pitches in transitions by steps or by slides. Some transitions are predominantly sliding or gliding in character with pitches but roughly approximated. In transitory syllables which lie between two syllables widely separated in pitch, the pitch may be an almost pure glide. This latter condition is seen in Fig. 16, Plate IV; and in Fig. 29, Plate V. Transitions up to and down from a certain pitch often appear in the form of circumflexes. For example, Fig. 23, Plate IV, is characteristic of such a situation. So long as there is a continuation of vibration of the vocal cords during changes in tetanus of the vocal musculature, slides will result.

(D) *Effect of consonants upon pitch-patterns.* Voiced consonants before a vowel have a tendency to lower the pitch in the attack of a syllable, and voiced consonants causing almost complete or partial obstruction have the same tendency. Voiced consonants do not always cause obstruction, however. Fig. 48, Plate VI, is a good typical example. The first " d " caused no great obstruction, hence the pitch remained essentially unaltered. The " d " in the final syllable, however, cause an almost complete obstruction to the passage of air. There is at this juncture in articulation, a sudden lowering of pitch followed by a return. Physiologically it seems that the sudden compression of air within the oral cavity produced by the obstruction of the tongue forces the posterior portion of the tongue down and with it, a downward change in the vertical movement of the thyroid is effected indirectly through the hyoid, thus resulting in an increase in the length of the cords. As a matter of fact, exaggerated changes in

the position of the tongue result in marked shifts of pitch during these changes. There seems to be a relation between control of the articulatory organs, especially the tongue and the other organs producing obstructions to the passage of air, and the regularity of pitch and pitch changes.

A vowel following an initial voiced consonant which offers only partial obstruction results in a slight lowering of pitch followed by a return. This is explainable on the same basis as the aspirated attack in the next paragraph.

The particular nature of the consonantal attack depends upon the relation of the pitch of the previous syllable, the position and shifts of the tongue and connected organs, and nature of the breath-stream.

(E) *Some general effects.* In an initial aspirated attack of a vowel, there is a tendency toward a temporary lowering of pitch followed by a rise in pitch. Fig. 52, Plate VI, was taken as typical of such movements. The particular extent of such changes in pitch depend upon the initial pressure of air that is forced against the cords. Physiologically, it seems that sudden releases of air tend to effect a momentary upper displacement of the vocal cords opening the rima glottidis and increasing the length of the cords. A quick return to their proximal position is made following the release of air.

The release of vowel sounds varies with individuals, as does the attack. In some instances there is a clean-cut attack and release; in other instances there is a slide into and away from the physically dominant pitch. When one syllable is of a higher pitch than another, the attack is generally by a glide, the extent of the glide depending upon the distance of the lower syllable from the higher and the nature of the consonant or vowel sound between the lower and higher pitches. A voiceless sound tends to shorten the extent of the slide, the slide being very short up into the higher syllable; a voiced sound or vowel forms a continuation of sound or glide from one pitch to another.

3. *Pitch periodicities.* These are classified under three general headings, although each pattern of pitch oscillation in each class is unique.

(A) *Variations from wave to wave.* In the graphs showing gross progression of pitch, it is evident that changes are more or less irregular. Some changes are relatively regular. The classification of these wave to wave fluctuations can not be made at present. They corroborate the descriptions of previous investigators.

(B) *Paired periodicities.* *Travis* (16) made slight mention of an occasional periodicity of 1/25 sec. superimposed upon a tremolo. Fig. 27, Plate II, is an example of this periodicity which is beautifully regular, as wave-length readings in this instance show. Fig. 9, Plate I, and Figs. 25, 27, 23, 28, 24, 22, and 29, Plate II, are smooth curves of the same periodicity in both male and female voices. A summary of the facts characteristic of these periodicities shows:

(1) These pitch fluctuations occur in pairs. It is very exceptional that two pairs should come close together such as in Fig. 22, Plate II.

(2) They occur during the phonation of a vowel and may be found in the attack, in the termination, or in the maintenance of the vowel.

(3) They vary in total pitch-range from one-fourth of a semitone to two or three tones; the mode seems to be about one or two semitones.

(4) It makes no difference in what part of the scale the predominant pitch lies, the period remains approximately the same. Thus the period is independent of the factor of pitch.

(5) They may occur in slides or glides as well as in so-called sustained speech sounds.

(6) Although it is not yet known whether they are characteristic of any particular mode of speaking or not, they have largely been found in ordinary communicative speech.

(7) They are not always present; in fact they are absent in the majority of cases of calm propositional speech.

(8) The period is most generally 1/20 second, although very minor deviations from this period may be present.

(C) *Grosser periodicities.* Grosser periodicities similar to those described by *Gray* and *Forchhammer* were found only in

very emotional and highly dramatic speech, never in calm communicative speech. The particular pattern of periodicity varies markedly, both in rate, extent, regularity, and form. They occur in so-called sustained tones as well as in inflections, as reported by *Gray*. They seem to fall into two general classes.

(1) Periodicity of a rate from 6 to 8 per second, such as in Fig. 14, Plate I, and Fig. 30, Plate II, which report the highly dramatic speech of Julia Marlowe.

(2) Periodicities at the rate of 10 per second. These do not exhibit the same regularity as the former. Fig. 17, Plate II, shows a type of periodicity which while retaining approximately the same rate, exhibits a number of forms. Two fluctuations appear after the slide downward from a level pitch. They take the form of a leveling of pitch, interrupting the general nature of falling movement and meet the description of the " drift " as pointed out by *Gray* (**2**, p. 358).

Fig. 18, Plate II, is a record of direct photography from a person saying " Oh " in a simulated experience of pain. With the exception of a large span embracing a period of 1/5 second and which is a reverse periodicity, inasmuch as the hump rising from A♯$^1$ to B$^1$ normally would fall to almost G, there is fair regularity in the rate of 10 per second. Fig. 13, Plate III, if from the radio announcement by Graham McNamee, showing the periodicity of 1/10 second in the rising attack of the word " last."

*Combinations of periodicities.* The records show, for the most part, irregularities in rate of occurrence as well as in form and extent. All four types of oscillations in pitch are seen in various physical frequency-patterns, namely (1) wave to wave fluctuations, (2) paired periodicity of 1/20 second, (3) periodicities of a rate from 6 to 8 per second, (4) those at the rate of 10 per second. In the interpretation of graphs, care must be taken not to class an initial attack as a periodicity, for example, Fig. 12, Plate I, is a graph of the changes in frequency in the word " mother " as spoken by Graham McNamee in the reception to Colonel Lindbergh at Washington, D. C., after his notable transatlantic flight. There is a characteristic attack of a semivowel, " m," followed by a vowel and a voiced consonant. The sound

"er," however, partakes of all the physical attributes of a vowel and has a pair of oscillations of a periodicity, each approximating 1/10 second.

4. *Summary.* A physical analysis of the pitch factor in speech based upon wave-length readings shows the same characteristic and syllabic pitch-patterns that were found in a perceptual analysis. There are individual differences in the evenness of pitch. Many syllables show a remarkably definite and evenly maintained pitch even in a very short duration. Although glides are more or less a characteristic part of the pitch-patterns in speech, there are tendencies toward definite pitches. Individual differences in the control of pitch and total patterns used make for differences in definiteness. In previous studies, the smoothed readings have blotted out these very significant findings. The mode of transition must be by slides in the case of voiced connectives between syllables, and of perfect or sliding transitions in the case of voiceless connectives. The slide in many instances is seen to be an incident in the change in pitch rather than the major characteristic. Movements from one relatively definite pitch to another forming more or less definite intervallic movements are evident. Minor changes in pitch resulting from changes in the position of the organs of articulation which affect the length of the vocal cords through vertical movements of the thyroid cartilage are also present. The particular changes of pitch which result depend upon the direction of change and nature of previous and succeeding vocal sounds. In many characteristics of frequency-patterns, individual eccentricities have been found which may be described in terms of wave-to-wave deviations, maintenance of a particular frequency, nature and extent of transition, and characteristics in the attack and release of syllables.

The following major facts with reference to pitch periodicities have been reported:

1. Three main types of fluctuations in pitch are present in speech:

(a) Variations from wave-to-wave which seem to have no regularity in occurrence and which constitute a major field of unsolved problems in speech.

(b) Paired periodicities of a period of 1/20 second which have been found in ordinary communicative speech.

(c) Grosser periodicities at rates of from 6 to 8, and of 10 per second which evince variations in regularity, extent, and form, and which are found only in emotional and highly dramatic speech.

2. Most normal fluctuations in pitch are composed of combinations of the above three types.

3. The regular fluctuations found in artistic dramatic speech seem to be built upon the natural fluctuations in pitch in emotional speech.

## III. Relationship Between Physical and Perceptual Pitch-patterns

The limitations imposed in the present analysis are auditory acuity of a high order, focus of attention under experimental conditions, average inflectional habits, and training in general observation of auditory phenomena.

1. *Procedure.* In order to have a precise basis for comparing the physical and perceptual pitch-patterns, it was necessary that the frequency of each of the reeds of the organ used in reporting perception be known. These frequencies were securd by readings made directly from the Seashore tonoscope in terms of 1/2 d.v., using a microphonic transmitter suspended within the organ housing in a position to receive the tones as they were produced singly.[13] Three readings of each organ tone were taken at different times as a check upon the accuracy of reading. Thus, knowing the report of an *O*, transpositions could readily be made into the physical scale used in wave-length readings and plotting.

The major source for the derivation of statements of relationship was the 81 syllables analyzed by 13 *O*s. Wave-length readings were taken as the physical description. The modal pitch-pattern of the 13 *O*s was taken as a perceptual basis of comparison.[14] The graphic pattern of perception was superimposed

[13] I am further indebted to Dr. H. M. Williams for assistance in taking these readings.

[14] The mode was considered more representative than a calculated average which no *O* reported. The variability in dominantly perceived pitch and inflection range among the *Os* is presented in the appendix of the original report filed in the Psychological Laboratory of the University of Iowa.

upon the physical pattern, thus affording a visual representation of relationships. This is seen on Plates III, IV, and V.

To supplement this comparison, the records of *Metfessel* (7) and *Merry* (6) were compared with the reports of observations of 3 *O*s of the same speech material. This added some 700 different syllables to those reported by the 13 *O*s above. Perceptual patterns were superimposed also upon *Metfessel's* and *Merry's* graphs. These, however, can not so readily be used for the derivation of statements of relationship since the physical patterns are smoothed readings.[15]

2. *Statements of general relationship.*[16] Throughout the report the physical pattern is stated first, followed by the perceptual pattern. Illustrations are given so far as possible from Plates III, IV, V, and VI, which have physical patterns more precisely calculated. An abundance of material is at hand, however, to constitute adequate evidence for all the principles presented.

The effect of duration of speech stimuli can, in a very general way, be reported as follows: the shorter the duration, the greater is the tendency to perceive a unipitch. Unipitch syllables showed the following figures as to duration:

| | |
|---|---|
| Range | .02 — .60 seconds |
| Mean | .162 |
| Median | .105 |
| S. D. | .089 |

Multipitch syllables showed the following figures as to duration:

| | |
|---|---|
| Range | .13 — 1.32 seconds |
| Mean | .42 |
| Median | .38 |
| S. D. | .208 |

I. In generally level pitches (where there is a definite level; where there is practically no sweep or a very swift sweep into

[15] This material is also available at the Psychological Laboratory of the University of Iowa.

[16] These statements of relationship have been derived from pitch-patterns in their complex setting in the speaking voice. Control of variables such as duration, intensity, range of pitch change and timbre have not been made. It is possible through a mechanical device, however, to control these variables and derive statements of psychophysical relationships for tonal patterns similar to those found in speech in both a quantitative and qualitative study. The principles so derived can analogously be used to describe the psychophysical relations in speech. Such a mechanical device has been designed and a preliminary investigation begun by the present writer.

or away from a level pitch; or where consecutive waves vary around a mean) a unipitch is perceived.

A. Where there is a physically level pitch, the perceived unipitch is identical with the physical pattern (see, for example, the first syllables in Figs. 30 and 42, and the second syllable in Fig. 36, Plate V).

B. Where, physically, there is a variation of consecutive waves about a mean, the mean pitch is perceived as characteristic of the mass, although there is a qualitative perception of roughness and sometimes an indefiniteness which is a function of the degree of variation (see the second and third syllables in Fig. 1, the word in Fig. 6, and the second word in Fig. 14, Plate III).

II. In movements from one relatively sustained or level pitch to another within the same syllable.

A. When the movement is rising and the two terminal pitches have practically equal duration, they are exactly perceived with a slide connecting them which is less dominant (see the first movement in Fig. 35, Plate V).

B. When the movement is falling, the upper pitch is perceived exactly, while the lower pitch tends to be perceived sharply (see the movement downward in Fig. 35, Plate V), although where the intensity[17] of the two does not materially change or the duration of the lower is relatively great, there is a parallel relationship between the physical and perceptual pattern (see the last movement in Fig. 21, Plate IV). In falling movements from one pitch which is physically approximated, to another of the same kind, there is a tendency to perceive certain definite intervals parallel with the physical pattern (see Fig. 31, Plate V). When the upper pitch is of brief duration and the lower pitch is of long duration, the upper pitch is perceived flat while the lower pitch is exactly perceived (see the last movement in Fig. 21, Plate IV).

III. Rising movements toward a more or less definite and maintained pitch.

[17] This was based on a subjective judgment.

A. When the sweep is relatively short in extent and of brief duration, while the upper pitch is of relatively long duration, or of intensity, the sweep is not perceived (see Fig. 38 and the fifth syllable in Fig. 29, Plate V).

B. When the sweep is longer in extent, the fact of a sweep is perceived, although not its extent (see the fourth syllable in Fig. 1, Plate III).

C. When the sweep is of longer duration, it is perceived as such although with less dominance than the upper pitch. The longer the duration, the more definite is the sweep perceived (see Fig. 7, Plate III).

V. In a falling movement toward a more or less definite pitch. When the sweep is relatively short in extent or of brief duration, the sweep is not perceived as such and the lower definite pitch is dominant (see the second syllable in Fig. 3, Plate III).

VI. Where there is movement up to and down from a more or less definite pitch:

A. In circumflexes of relatively short duration, a unipitch is perceived which is somewhat lower than the highest part of the physical pattern (see Fig. 1, Plate III; Figs. 33, 38, and 46, Plate V).

B. When the upper pitch is of relatively long duration, and the sweep into and away from of short extent or of brief duration, a unipitch is perceived which is co-extensive with the physical level of the upper pitch (see the third syllable in Fig. 33, Plate V).

C. As the sweeps up and down increase in duration, they are more and more definitely perceived (see Fig. 11, and Fig. 15, Plate III).

VII. In pure glide tones (which are found in intermediary syllables constituting swift transitions from a lower to a higher pitch or *vice versa,* or in the end of phrases or melodic sequences).

A. In rising or falling glides of small extent and brief duration, a unipitch is heard which is indefinite and localizable at almost any point on the glide (see the sixth syllable in Fig. 29, Plate V).

B. In slightly longer slides, a unipitch at the middle of the slide (see Fig. 29, second syllable, Plate V) is perceived as characteristic of the whole syllable.

C. In rapidly falling movements of large extent, where the intensity is low, the extent and boundaries of the slide are located and are only referable to some indefinite lower pitch. The point of reference varies with *Os*.

D. In pure rising or falling movements of long duration and great intensity, the entire slide as such is perceived.

1. In rising movements, as the pitch rises, it is gradually perceived; the upper termination is perceived as dominant.
2. In all slides, it takes time to build up sound in consciousness, hence beginnings of pure slides are rarely perceived.

VIII. In complex slides. Any portion of a slide that is maintained for a longer time than any other is perceived as dominant; and this portion, in slides of relatively small extent, tends to overshadow the others in perception (see the second syllable in Fig. 16, Plate IV), although where several of such portions are present, any one may be perceived as dominant (see Fig. 29, sixth syllable, Plate V).

IX. In transitions from syllable to syllable:

A. In transitions from one syllable to another, separated by a consonantal break, each syllable is perceived as a unique pitch-pattern (see Plates III, IV, and V).

B. Where two syllables follow each other without a consonantal break, there is a uniqueness about the perception of each syllabic pitch-pattern, although the continuation of sound may or may not be definitely perceived (contrast Fig. 43 with Fig. 36, Plate V).

C. In swift transitions from a higher to a lower pitch, where the lower is of weaker intensity, the lower pitch is generally judged sharp of the physically dominant portion. This also holds true in rapid transitions from lower to higher pitches and in certain types of circumflexes.

X. Very brief syllables are frequently misjudged, the tendency being to judge sharp.

XI. In complex movements: when any complex pattern has sufficient duration, spread equally throughout its course, it is perceived in its total pattern (see Fig. 17, Plate IV, and Fig. 45, Plate V).

XII. Pitch periodicities at a rate of ten per second or less, such as the vibrato, are perceived as periodicities, the perceived pitch, characteristic of the syllable, being a mean of the physical pattern of the oscillation (see Figs. 3 and 12, Plate III). Pitch periodicities at a rate greater than ten per second are not perceived as such, the perceived pitch being a mean of the physical pattern of oscillations (see Fig. 8, Plate III, and Fig. 22, Plate IV).

XIII. The frequency-pattern of the vowel was perceived as the pitch-pattern of the entire syllable except where voiced consonants were of relatively long duration and great intensity in which case the pitch of the voiced consonant was perceived according to the principles above stated but with less dominance than the vowel (see Figs. 19 and 24, Plate IV, and Figs. 33 and 42, Plate V; and Fig. 22, Plate IV, and Fig. 35, Plate V).

XIV. Qualitatively, pitch-patterns which evinced wide variations from wave to wave were perceived as rough or noisy (see Fig. 4, and the fourth syllable in Fig. 1, Plate III) while those which evinced rigidity or evenness from wave to wave were perceived as smooth or tonal (see the second syllable in Fig. 36, Plate V).

It is evident in comparing the results of this section with those reported by *Peters* (11) that his statements have been corroborated and amplified in the present investigation so far as the relations between physical and perceptual pitch-patterns are concerned. We have found that the total pitch or tonal range need not be rather large, as *Peters* concluded, in order to permit of the perception of a dominant pitch. The *O*s used in the present

experiment were able to divorce the factor of timbre or clang quality in locating the pitch perceived, and, so far as pitch was concerned, did not experience the difficulty which *Peters* reported, in the location and differentiation of pitch-patterns, although some syllables were somewhat indefinitely perceived as previously reported.

*General conclusions.* Through a comparison of perceptual and physical pitch-patterns in speech added verification is given for the statements that in speech there is a tendency to strike toward a more or less definite pitch, that movements tend to evince an intervallic relationship between pitches, that the slide is an incident resulting from the nature of the speech sounds and the action of the vocal musculature. Statements of relationship between the physical and perceptual pitch-patterns have been made which will be of value in the interpretation of future physical studies of the pitch factor in speech.

Syllabic pitch-patterns have been characterized by:

1. Presence or absence of pitch periodicities
   A. Types
      (1) Wave-to-wave fluctuations.
      (2) Paired oscillations whose period is 1/20 sec.
      (3) Grosser fluctuations of periods of 1/6 to 1/8 sec., and 1/10 sec.
   B. Characterized by
      (1) Regularity of period and range.
      (2) Particular total temporal pattern.
2. Presence or absence of pure glides in terms of extent or range of movement and complete pattern of glide.
   A. As characteristic of all syllabic patterns.
   B. As characteristic of swift transitional syllables, between a high and a lower syllable or *vice versa*.
3. Tendencies of glides or tonal movement toward or away from a single dominant pitch.
4. Definiteness of pitch or pitches evinced.
5. Degree of rigidity or tonality in the maintenance of single pitches.

6. Degree of regularity in tonal movement or change in pitch.
7. Presence or absence of intervallic movement.
   (1) Variations in extent.
   (2) Variations in number of intervallic changes—diphthongs or triphthongs.
8. Nature of transitions from syllable to syllable in terms of the above seven rubrics.

Larger melodic patterns are composed of these smaller syllabic patterns and may be classified through a characterization in terms of various patterns of syllabic sequences and their recurrence.

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## Plates

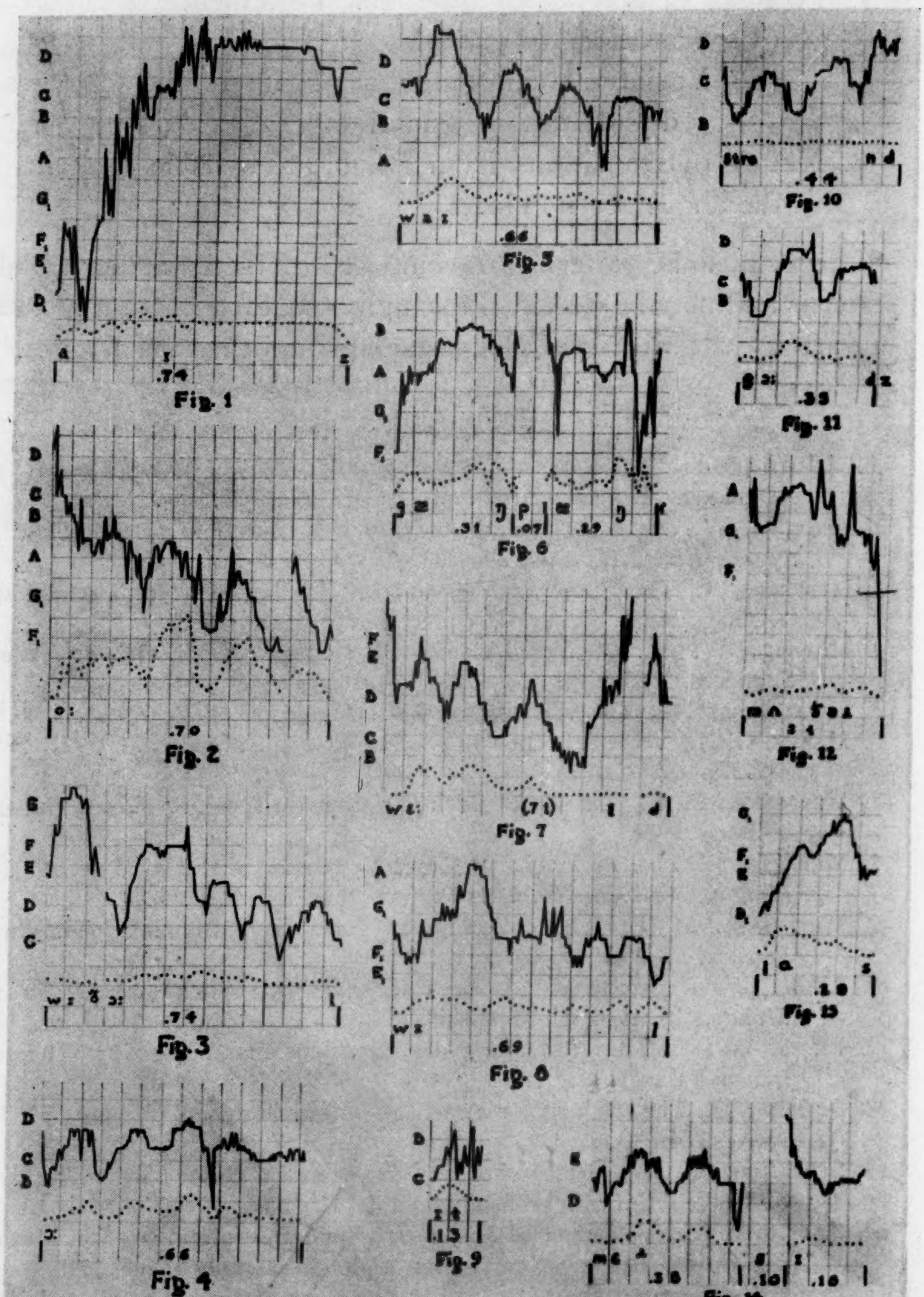


PLATE I. *Pitch periodicities in speech*

Each vertical square represents a semitone; each horizontal square represents a time-unit of .05 second. Dotted lines at the bottom of each graph represent the amplitude of sound waves, with each vertical block representing 5 mm. height. Words are printed in phonetic symbols. Numbers at base of each graph refer to the time-unit as between the vertical lines bounding them in terms of seconds. C represents middle C (256 d.v.), $C_1$ the octave below, $C^1$ the octave above, *etc.*

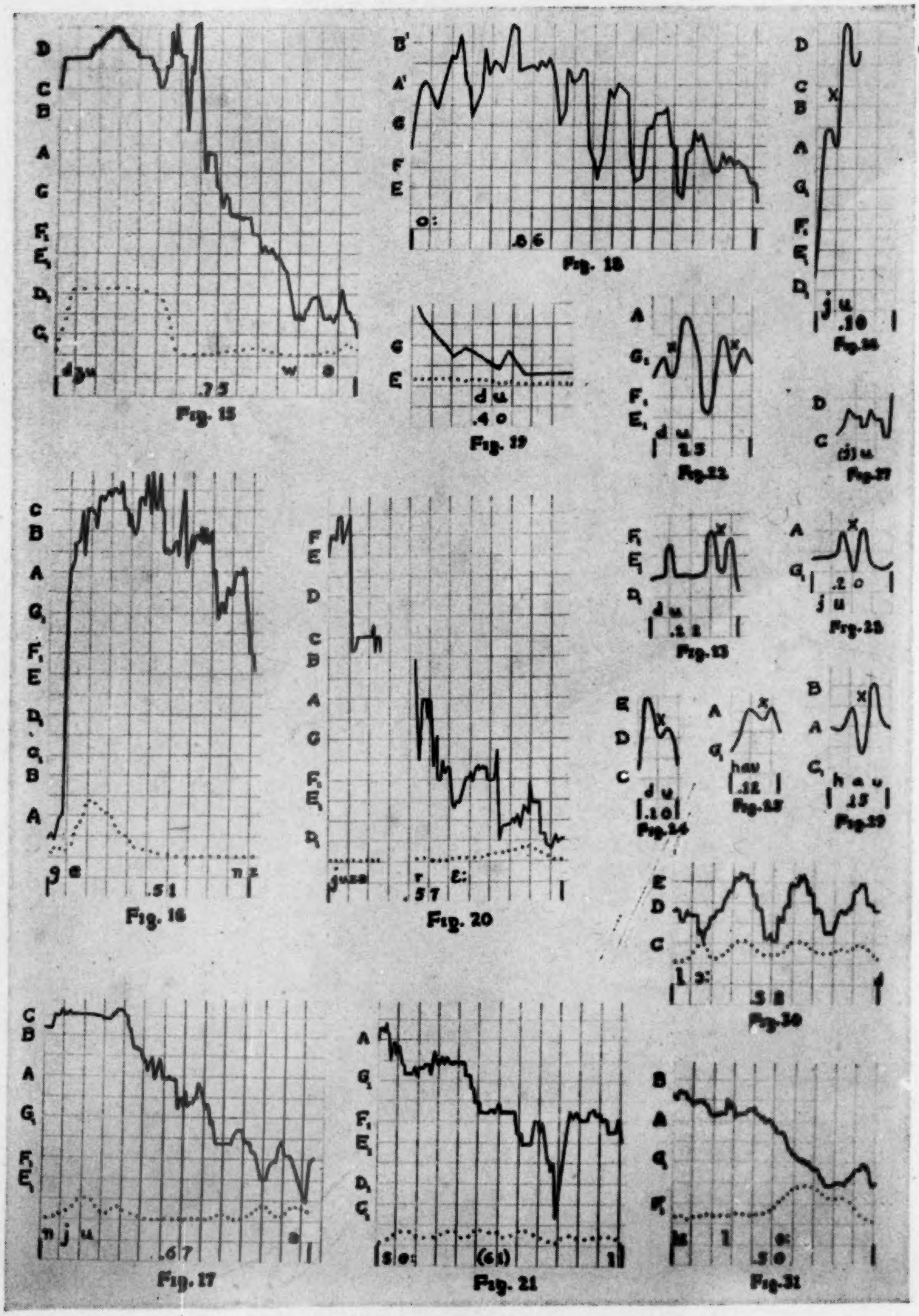

PLATE II. Pitch periodicities in speech.

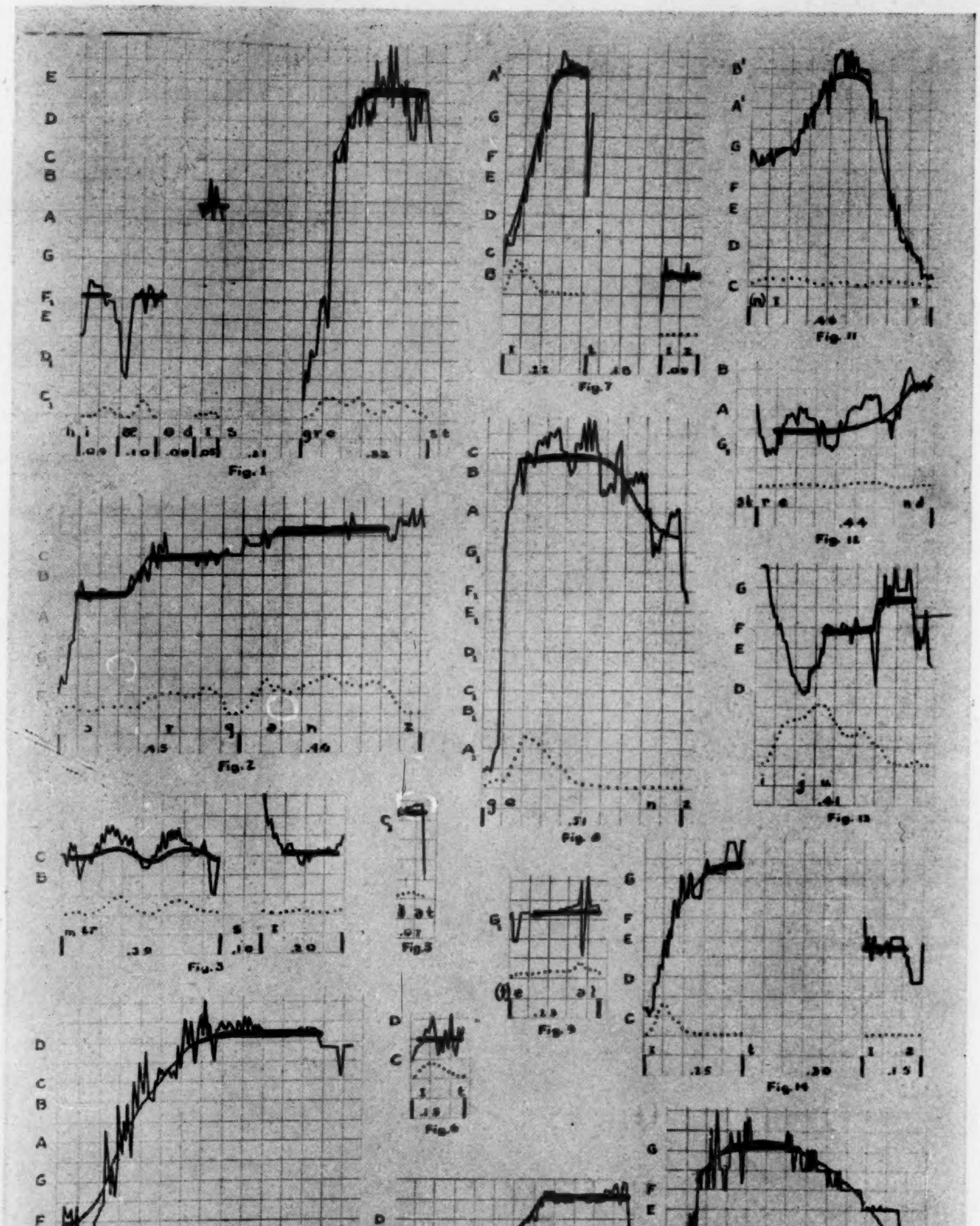

PLATE III. Selected syllabic pitch-patterns.

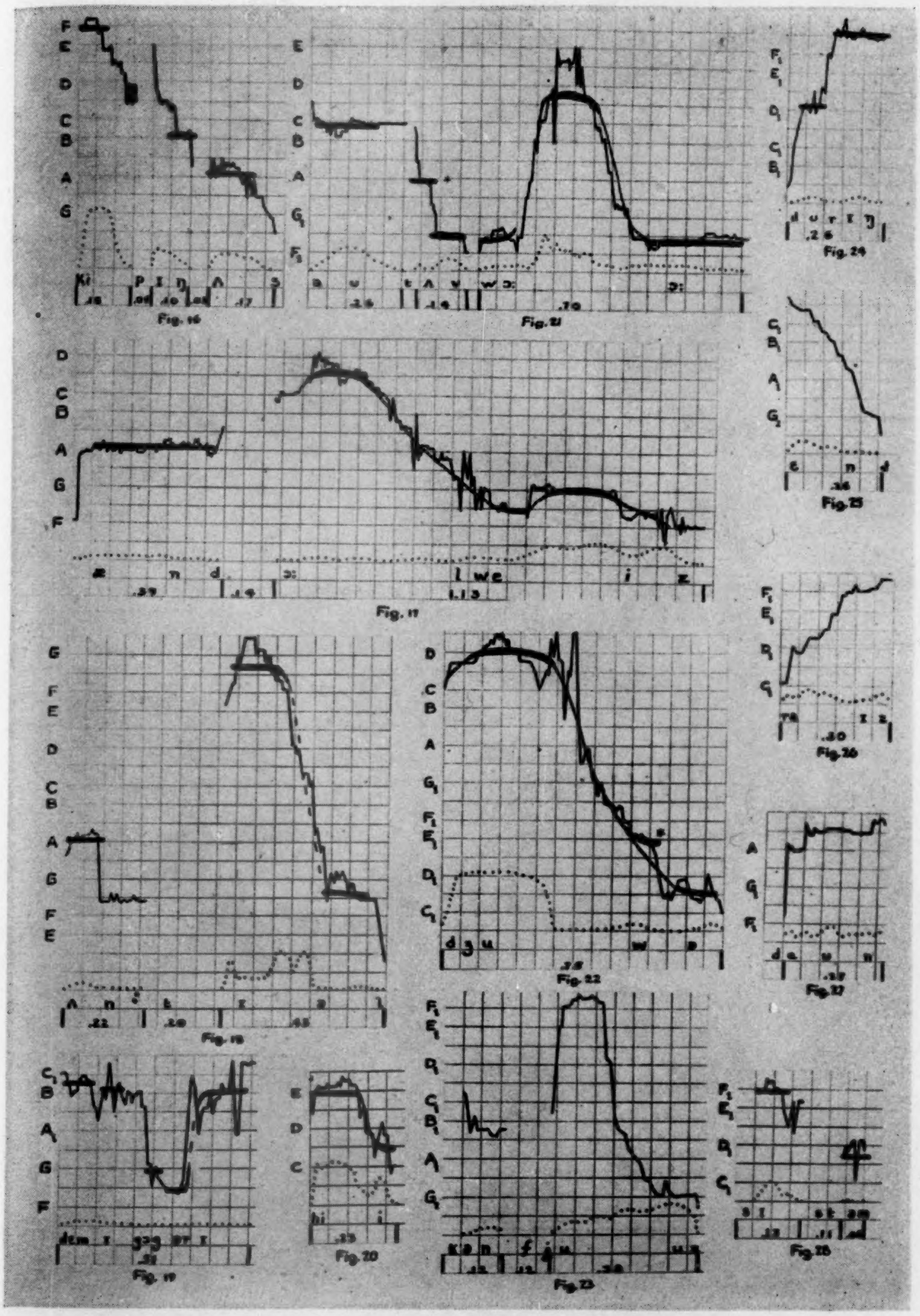

PLATE IV. Selected syllabic pitch-patterns.

* Three of the 13 *O*s perceived the lower pitch here. The perception in their case appears somewhat illusory. Several other cases of such illusions are at hand.

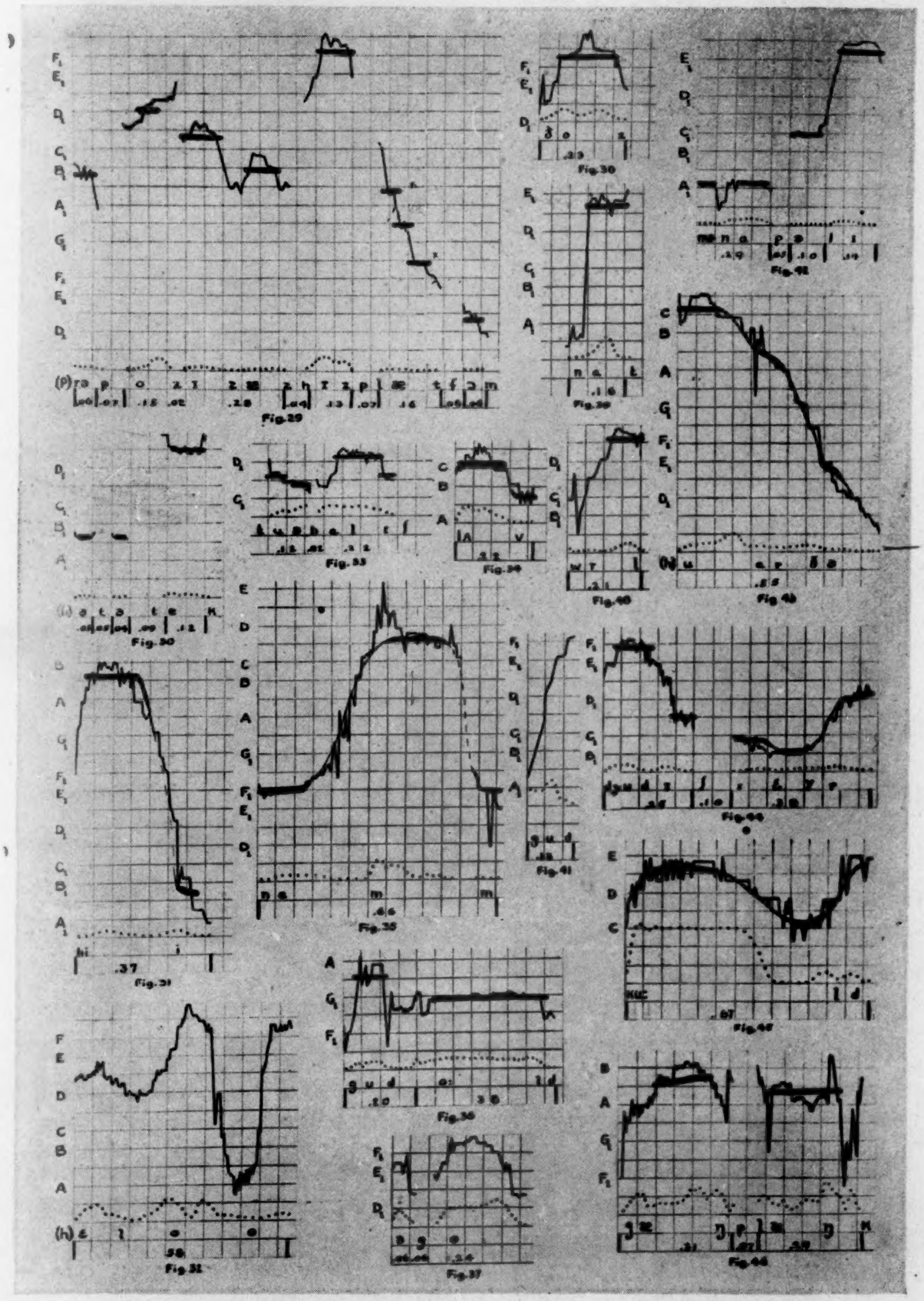

PLATE V. Selected syllabic pitch-patterns.

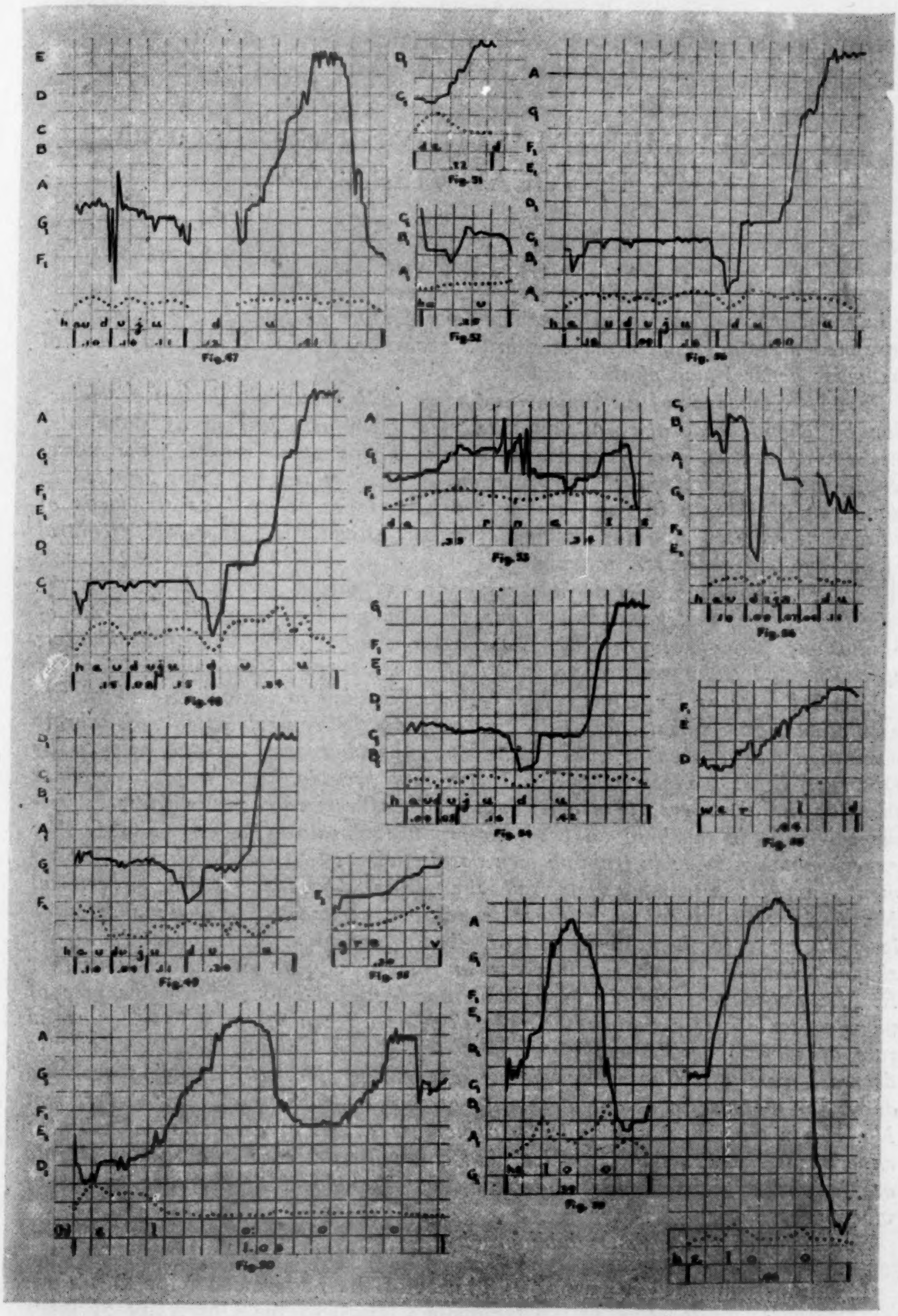

PLATE VI. Selected syllabic frequency-patterns.

# AN EXPERIMENTAL STUDY IN CONTROL OF THE VOCAL VIBRATO[1]

BY

ARNOLD HENRY WAGNER

*Introduction: theories of control of vocal vibrato; undesirable pulsations: unrefined vibrato; refinements of vibrato necessary to artistic singing; general methods; general plan of this work.*

Part I. *Standards of attainment in singing with beautiful vibrato: reproduction by phonophotography of tones selected from best singers as standards; method, apparatus, and technique used for phonographic records; the wavelength method of reading; interpretation of graphs; artists' tones selected as standards of vibrato in calm singing; artists' tones selected as standards of vibrato in agitated singing; method of using "standards" as models; control of amount and character of training.*

Part II. *Methods of training: methods and media for production of the vibrato; general instructions; metronome technique for the control of rate of oscillation; phonophotographic technique for control of extent of oscillation; apparatus and technique used; reading of films; types of observers.*

Part III. *Data: Experiment No. 1–A: in learning to control rate of vibrato oscillation; experiment No. 1–B: in learning to control extent of vibrato oscillation; experiment No. 2: showing unusual control of the vibrato by Observer C. H.; experiment No. 3: training pre-adolescent boys to produce vibrato; the observers; plan of training; procedure and case histories; experiment No. 4: in teaching an adult to produce vibrato—Observer H. M. W.; experiment No. 5–A: in training men vocal students to produce vibrato; experiment No. 5–B: in training women vocal students to produce vibrato; experiment No. 6–A: case studies in increase in rate; experiment No. 6–A: showing a learning curve for increase in rate of vibrato oscillation; experiment No. 6–B: showing learning curve for increase in rate of vibrato oscillation—Observer R. M.; experiment No. 7: in training vocal students to increase the rate of vibrato oscillation; experiment No. 8: showing a learning curve for decrease in rate of vibrato oscillation; experiment No. 9: in training vocal students to decrease rate of vibrato oscillation; experiment No. 10: showing learning curve for increase in extent of vibrato oscillation—Observer J. T.; experiment No. 11: in training vocal students to increase extent of oscillation of vibrato; experiment No. 12: showing a learning curve for decrease in extent of vibrato oscillation; experiment 13: in training vocal students to decrease extent of vibrato oscillation.*

*Summary of conclusions; bibliography.*

[1] A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the Graduate College of the University of Iowa, August, 1928. Grateful acknowledgment is hereby made to Dean Carl E. Seashore whose scientific insight, thoughtful direction and enthusiasm for the problem have made the working out of this study possible. Acknowledgment and appreciation are also expressed to Dr. Milton Metfessel for invaluable advice on questions of technique and treatment of data.

## INTRODUCTION.

The purpose of this study was to gather data on the possibilities for control of the vocal vibrato with special reference to the pedagogy of singing.

*Theories of control of vocal vibrato.* Many theories have been advanced, and none proved, as to the source of control of the vibrato. Popular among singing teachers having some knowledge of the physics of sound is the belief that the vibrato is a phenomenon resulting from beats or interference of overtones. This belief in turn gives rise to the equally prevalent belief that nothing can or should be done directly to control or produce the phenomenon, since it should remain a natural attribute of a tone which is rich in overtones. *Louis Graveure,* singer and teacher of international reputation, states (2) that he does not consider any fluctuation of the voice to be a vibrato unless it is controlled by the diaphragm. *Schoen* (10) states that the vibrato is in every respect a phenomenon similar to involuntary tremor. Introspections of the observers taking part in this experiment and observations of the writer during twenty years of voice teaching, point to the conclusion that the most pleasing vibratos are not controlled by any one localized muscle or set of muscles but by the synergic or alternate (14) action of many, perhaps all, of the muscles having to do with respiration and phonation. Just what muscles are employed in the production of the vibrato, however, remains to be experimentally determined.

*Undesirable pulsations: unrefined vibrato.* There is among laymen and musicians no clearly defined difference between vibrato and tremolo. *Seashore's* tentative definition of the vibrato, quoted as follows, is taken in this study as a working basis (13, p. 467):

"Generalizing from a vast variety of concrete data at hand we may define the vibrato in calm and beautiful singing as a synchronous pitch and intensity oscillation, ordinarily at the rate of from five to eight oscillations per second, in which perhaps the most beautiful effect is obtained when the pitch oscillation does not exceed one-fourth of a tone and the intensity oscillation is as barely perceptible as the pitch oscillation and both take the

form of a smooth sine curve." Further, since vibrato of the type specified by *Seashore* characterizes the tones of all of the great artists analyzed through phonophotography in Part I of this study, as well as in the studies by *Metfessel* (8) and other investigators in this field, it is assumed that vibrato of the foregoing definition is a desirable attribute of the singing voice. The writer also subscribes to the statement by *Kwalwasser* (6) and *Metfessel* that exaggerated or badly controlled vibrato constitutes the so-called "tremolo."

The findings of this investigation are, however, contrary to the position taken by *Gray* (4): "Those variations in pitch and intensity which are the result of conscious effort, or which have been developed as a habit, from one having been consciously voluntarily produced, constitute, according to this interpretation, the tremolo; those which are produced or have been acquired or developed unconsciously, involuntarily, constitute the vibrato."

*Refinements of vibrato necessary to artistic singing.* The position taken in this study is that refinements of the vibrato as to rate and extent of oscillation are necessary to artistic singing; that the singer should know how to increase or diminish his rate and extent of oscillation at will; that he should develop conscious control over these factors so that he may know what to do in case his rate becomes too slow or too fast, or the extent of oscillation becomes inappropriate to the emotion being portrayed.

*General methods.* The phonophotographic method for the reproduction of tones was employed exclusively in this investigation. The Dorsey phonelescope was used throughout as an optical lever (1). Three types of phonophotographic apparatus were utilized: 1. A type employing two phonelescopes—one for a time or reference line and another for the voice, with film driven by a synchronous motor. 2. A type using one phonelescope adapted by *Simon* (15) and *Metfessel* (7) to phonograph record photography. Both of the foregoing types of apparatus were used in the psychological laboratory at the University of Iowa. 3. A studio type of phonophotographic camera designed after one by *Metfessel* was set up by the writer in connection with his own

vocal music studio.[2] Owing to the demands for the different types of apparatus used, both "time-line" and "wave-length" methods of reading films as described by *Simon* (15) were necessarily employed.

Since the phonelescope diaphragm has free or distorting regions which make intensity readings unreliable, this study was confined to the time and frequency factors involved in the vibrato, leaving the intensity factor for later investigation. For convenience of the reader, the various types of apparatus and techniques will be described as encountered in Parts I and II.

*General plan of this work.* In the reproduction of artists' tones from phonographic records in Part I of this study, no attempt was made to establish norms in rate and extent of oscillations of the vibrato. The artists' tones were simply used as models or samples to establish concepts of beautiful vibrato in the minds of the various types of *O*s taking part in the experiment. Since *Kwalwasser* (6) has shown that "the pitch and intensity fluctuation of the vibrato may be increased beyond their habitual boundaries, voluntarily, with little effort" no attempt was made in this study to investigate further methods of producing exaggeration in the vibrato.

In order to avoid the question as to whether or not specific training on sustained tones would carry over into artistic interpretative singing, the instructions and devices given to teach control of the vibrato were, from the first, applied directly to the singing of meaningful sentences and artistic songs. The song material was chosen with reference to the character of the intended correction and to the musical and general qualifications of the singer.

The problems under investigation then are:

1. Methods and media for producing refinements in control of (a) rate of oscillation of the vibrato, and (b) extent of oscillation of vibrato.

2. The possibility of teaching production of the vibrato, (a) to pre-adolescent boys and (b) to adults of both sexes.

[2] In the University of Southern California.

## Part I. Standards of Attainment in Singing with Beautiful Vibrato.

In order to set up standards of attainment to be used in teaching control of the vibrato, tones were selected as models from " red seal " phonographic records of nine well-known concert and operatic artists.[3]

*Reproduction by phonophotography of tones selected from best singers as standards.* *Seashore* (11) has shown the value of talking machine recordings for objective studies in speech and singing. Phonographic records were particularly well suited to this study for the following reasons: (a) By this method the voices of the best artists could be brought into the laboratory for objective analysis of the vibrato in tones selected as standards. (b) These same phonographic tones could later be used in the vocal studio for training students and other *O*s in control of the vibrato.

The tones photographed for this two-fold purpose were selected with the following points in mind:

(1) That the vibrato in the tones selected as standards should be beautiful and seem to be appropriate to the emotion being expressed.

(2) That there should be examples from each of the four types of voices—soprano, contralto, tenor, and bass.

(3) That samples of high and low or at least middle tones in each voice should be chosen.

(4) That there should be examples of vibrato in calm and agitated singing.[4]

(5) That the tones selected should be sustained, unaccompanied tones to admit of an accurate reproduction by phonophotography.

[3] With the exception of the Caruso and Chaliapin records the ones chosen were all new orthophonic recordings. Acknowledgment for coöperation and assistance in selecting the records and tones photographed is hereby made to Mrs. Frances E. Clark, Educational Director of the Victor Talking Machine Company, and Miss Marie Finney, Teacher of Music Appreciation in 1927 Summer Session of the University of Iowa.

[4] The idea of calm and agitation in emotional expression was taken from Wundt's tri-dimensional theory of affection.

*Method, apparatus, and technique used for phonographic records.* The Artist Series of phonophotographs for Part I were taken directly from the phonographic records using the technique perfected by *Metfessel* (7). The apparatus designed for this work requires that the records be fastened to the flat upper surface of a drum or turn-table around the circumference of which is wound a strip of supersensitive moving picture film about six and a half feet in length. Since the record is bolted securely to the turn-table, both record and film are revolved synchronously. A phonelescope[5] is mounted in front of the turn-table. The receiving horn of the phonelescope is connected with a specially constructed tone-arm. In photographing, the motor is started and the record played on this improvised phonograph. When the desired tone on the record is heard, the film is exposed by reflecting the beam of light from the mirror of the phonelescope to the center of the film for one revolution of the turn-table. Thus a picture of the artist's tone is procured. Owing to the sensitivity of the film to ordinary light, the photographing has to be done in an absolutely dark room.

After the photograph is taken and the film developed, it is necessary to read the variations in frequency and time which represent the vibrato. The artists' series of films in Part I were read by the "wave-length" method developed by *Simon* (15) and *Metfessel* (7). By this method, as is shown, no time or reference line is necessary.[6]

*The wave-length method of reading.* This method of reading frequency from the films in terms of wave-lengths was developed and described by *Simon* (15), who showed that the method has

[5] "Phonelescope" is the trade name of an optical lever manufactured by Herbert Grove Dorsey, Box 835, Washington, D. C. By means of this lever a beam of light is focussed on the film from a tiny revolving mirror. The mirror is activated by a diaphragm in the receiving horn of the phonelescope.

[6] Since the circumference of the turn-table (196.1 cm.) and the original rate of recording the phonographic record (78 r.p.m.) are both known, it becomes evident that a photograph taken during one revolution of the turn-table would represent one seventy-eighth of a minute or .77 second for the exposure of the 1961 mm. film. It is thus computed that the 2549.3 mm. would represent the length of film that would be exposed in a whole second.

a higher degree of reliability than is demanded for the purposes of this study. By the wave-length method, waves are measured either singly or in groups in terms of tenths of a millimeter. The rate per second of the film (2549.3 mm.) divided by the wave-length gives the frequency of each wave measured. In order to facilitate graphing, a work-table or scale was prepared giving the frequencies of all wave-lengths encountered in the film taken with this type of phonophotographic apparatus.

*Interpretation of graphs.* The graphing of the artists' tones in Part I and throughout this study is done to show: (a) horizontally, time in intervals of tenths of a second marked off by the heavy vertical lines; and (b) vertically, frequency in terms of a half tone, with interpolations for frequencies between the half tones of the tempered scale.

A word of explanation in regard to the meaning of certain of the terms may be helpful in following the descriptions which accompany the graphs of the artists' and other series of phonophotographs throughout the study: *frequency* is herein used to designate the number of sound-waves per second, while *pitch* refers to the sound experienced. The *mean frequency* of the tone sung was found by dividing the mean wave-length in mm. into the number of mm. which the film travels per second. The term *vibrato cycle-length* has reference to the length of one oscillation of the vibrato, shown on the graph (see Fig. 1) as the horizontal distance from a given point on one vibrato wave to a corresponding point on the next. In descriptions below the graphs and in the various tables of results in the study, the *average cycle-length* is expressed in terms of .01 second. *Rate of oscillation* means the number of oscillations per second. *Average extent*[7] of oscillation is expressed on the graphs in the average height of the vibrato waves shown, and in the descriptions and tables, in terms of per cent of a step. *Regularity of oscillation* refers to the variation of one cycle from another in any of its aspects. The aspects with which this study is concerned are, (1) rate; and (2) extent.

[7] The method of analyzing the vibrato, and the "four segment method" of finding average extent were taken from *Metfessel* (**9**).

*Artists' tones selected as standards of vibrato in calm singing.*

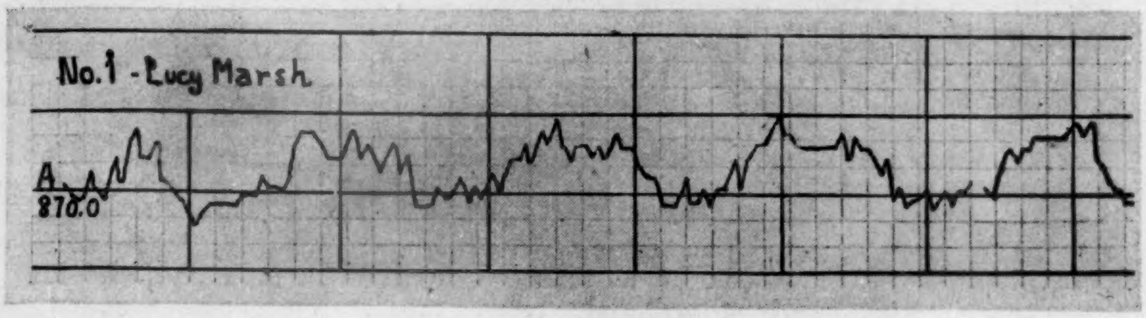


FIG. 1. Soprano: Lucy Marsh.

Space between heavy vertical lines—one-tenth second.[8]
Space between heavy horizontal lines—half tone.

Selection: "I Know that My Redeemer Liveth" (Handel), Victor Record No. 9104-A.
Emotion: calm.
Vowel photographed: "e" in "risen."
Location in selection: highest tone of aria near end of the selection.
Standard pitch nearest the tone sung:[9] A 870.0.
Mean frequency of the tone sung: 878.96.
Average vibrato cycle-length: .161 sec., A.D., .007.
Rate of vibrato oscillation: 6.2 per sec.
Average extent of oscillation: 30% of a tone, A.D., .00.

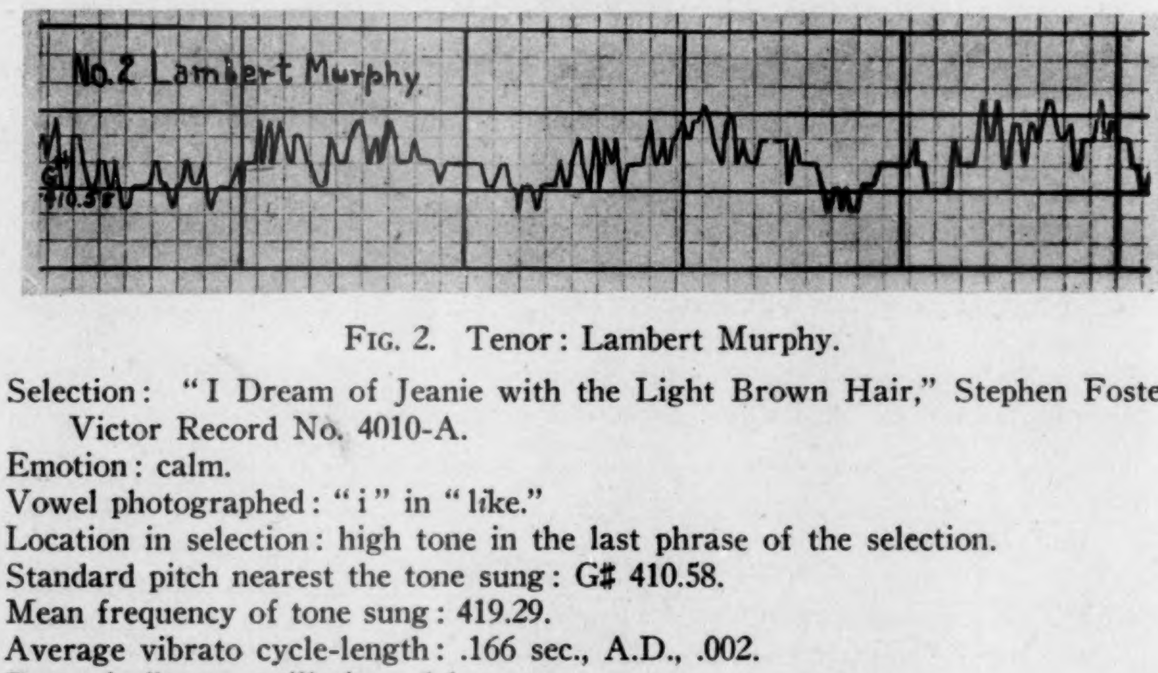


FIG. 2. Tenor: Lambert Murphy.

Selection: "I Dream of Jeanie with the Light Brown Hair," Stephen Foster, Victor Record No. 4010-A.
Emotion: calm.
Vowel photographed: "i" in "like."
Location in selection: high tone in the last phrase of the selection.
Standard pitch nearest the tone sung: G# 410.58.
Mean frequency of tone sung: 419.29.
Average vibrato cycle-length: .166 sec., A.D., .002.
Rate of vibrato oscillation: 6.6 per sec.
Average extent of oscillation: 40% of a tone, A.D., .040.

[8] Wide differences in wave-lengths, due to the various pitches on which the artists' tones were sung, accounts for the seeming inconsistency in the tenth of second intervals on the graphs of this series.

[9] The discrepancy between the standard pitch and the mean frequency of the tone sung might be due either to faulty intonation of the artist or to the tuning of the accompanying instrument.

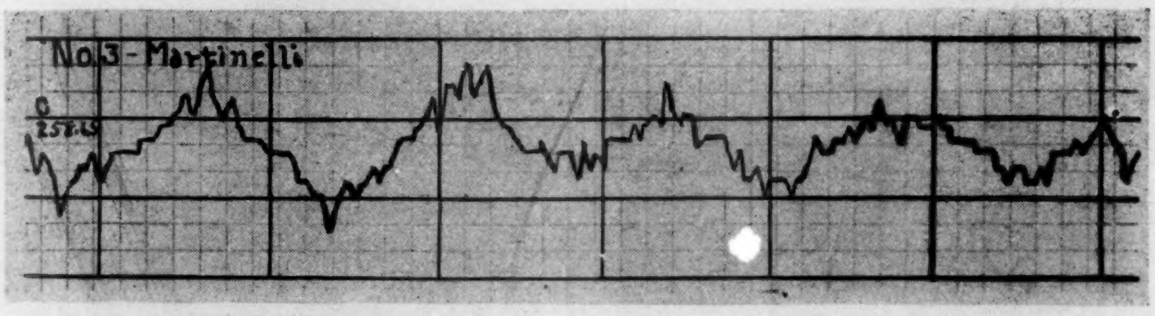


FIG. 3. Tenor: Martinelli.

Selection: "The Fatal Stone" duet from "Aida," Victor Record No. 3040.
Emotion: calm.
Vowel photographed: "e" in "mia."
Location in selection: last word of second phrase of the opening recitative.
Standard pitch nearest the tone sung: C 258.65.
Mean frequency of tone sung: 251.65.
Average vibrato cycle-length: .151 sec., A.D., .015.
Rate of vibrato oscillation: 6.6 per sec.
Average extent of oscillation: 40% of a tone, A.D., .075.

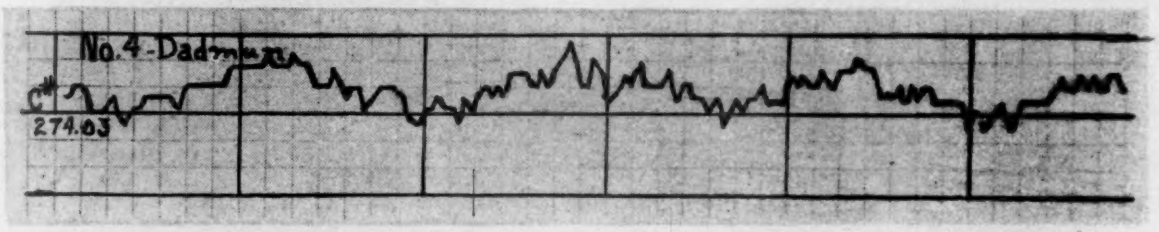


FIG. 4. Bass: Dadmun.

Selection: "Caro Mio Ben" (Giordani), Victor Record No. 4009-B.
Emotion: calm.
Vowel photographed: "a" in "caro."
Location in selection: first tone of the selection.
Standard pitch nearest the tone sung: C♯ 274.03.
Mean frequency of the tone sung: 277.06.
Average vibrato cycle-length: .159 sec., A.D., .010.
Rate of vibrato oscillation: 6.3 per sec.
Average extent of oscillation: 20% of a tone, A.D., .00.

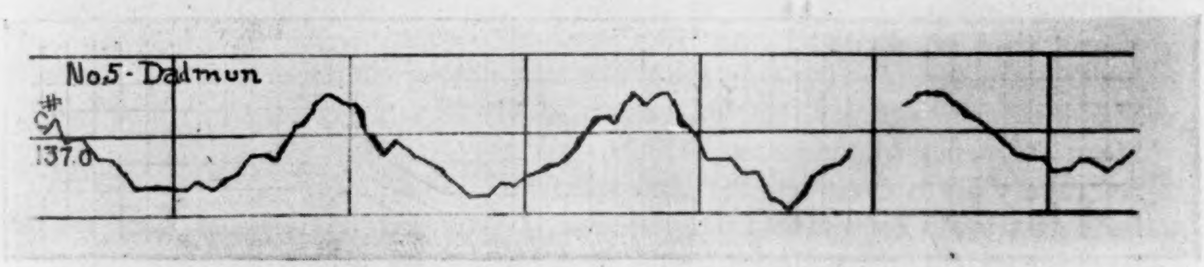


FIG. 5. Bass: Dadmun.

Selection: "Caro Mio Ben" (Giordani), Victor Record No. 4009-B.
Emotion: calm.
Vowel photographed: "o" in "cor."

Location in selection: last tone of the first stanza.
Standard pitch nearest the tone sung: C♯ 137.01.
Mean frequency of the tone sung: 134.74.
Average vibrato cycle-length: .175 sec., A.D., .007.
Rate of vibrato oscillation: 5.7 per sec.
Average extent of oscillation: 39% of a tone, A.D., .052.

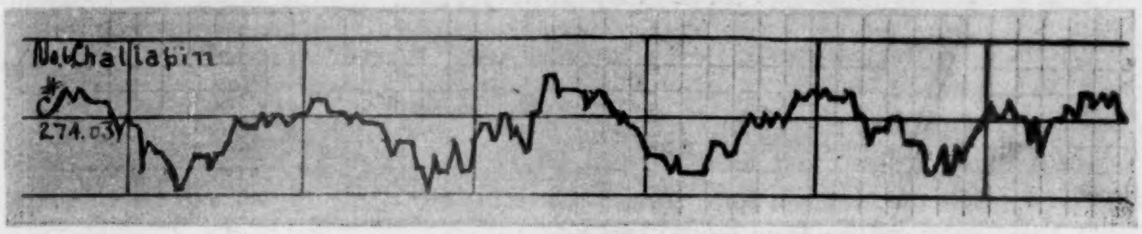


FIG. 6. Bass: Chaliapin.

Selection: "Vi ravviso" from "Sonnambula" (Bellini), Victor Record No. 981-B.
Emotion: calm, becoming an agitated crescendo toward the end of the tone which is held several seconds.
Vowel photographed: "o" in "tr*o*vo."
Location in selection: third syllable from the end of the selection.
Standard pitch nearest the tone sung: C♯ 274.03.
Mean frequency of the tone sung: 267.47.
Average vibrato cycle-length: .151 sec., A.D., .005.
Rate of vibrato oscillation: 6.6.
Average extent of oscillation: 36% of a tone, A.D., .048.

Artists' tones selected as standards of vibrato in agitated singing.

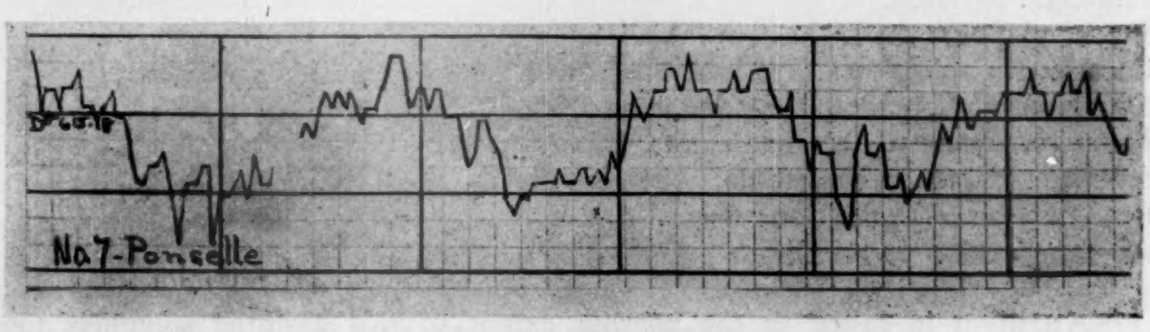


FIG. 7. Soprano: Ponselle.

Selection: "The Fatal Stone" duet from "Aida," Victor Record No. 3040-A.
Emotion: agitated, changing gradually to calm toward the end of the tone.
Vowel photographed: "e" in "m*i*a."
Location in selection: second syllable sung after her entrance in the duet.
Standard pitch nearest the tone sung: D♯ 615.18.
Mean frequency of the tone sung: 610.62.
Average vibrato cycle-length: .168 sec., A.D., .004.
Rate of vibrato oscillation: 6.0 per sec.
Average extent of oscillation: 60% of a tone, A.D., .00.

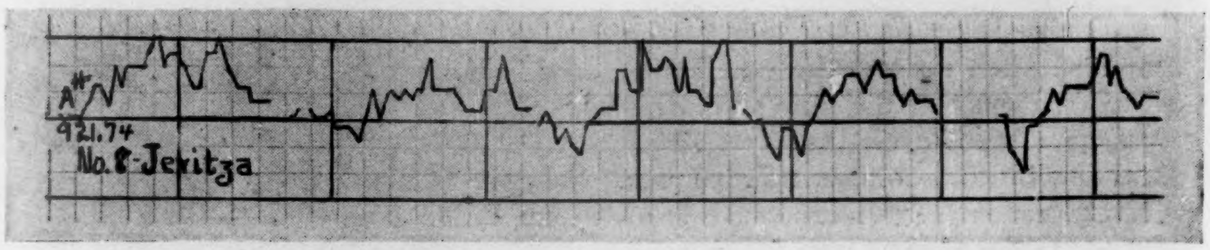


FIG. 8. Soprano: Jeritza.

Selection: "Adieu, Forests"—"Jeanne d'Arc,". Victor Record No. 6604-B.
Emotion: agitated.[10]
Vowel photographed: "a" in "*A*dieu."
Location in selection: last word in the selection.
Standard pitch nearest the tone sung: A♯ 921.
Mean frequency of the tone sung: 904.84.
Average vibrato cycle-length: .140 sec., A.D., .009.
Rate of vibrato oscillation: 6.9 per sec.
Average extent of oscillation: 26% of a tone, A.D., .056.

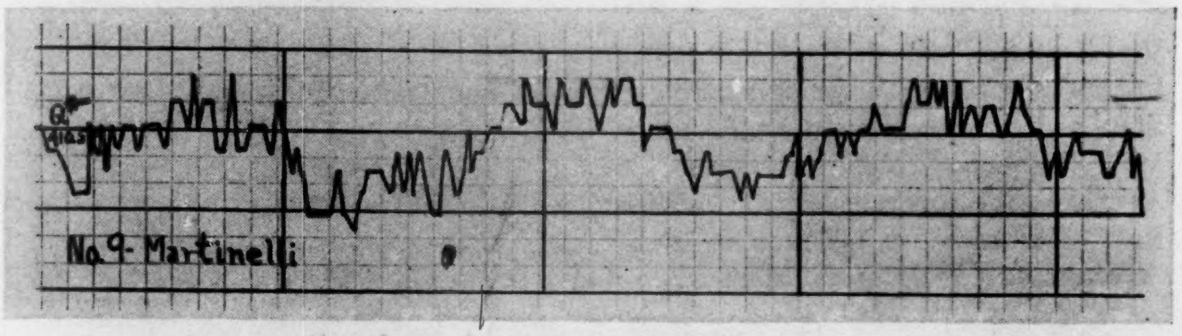


FIG. 9. Tenor: Martinelli.

Selection: "The Fatal Stone" duet from "Aida," Victor Record No. 3040.
Emotion: agitated.
Vowel photographed: "a" in "Ah."
Location in selection: first unaccompanied tone after Aida's entrance.
Standard pitch nearest the tone sung: G♯ 410.58.
Mean frequency of the tone sung: 427.67.
Average vibrato cycle-length: .154 sec., A.D., .013.
Rate of vibrato oscillation: 6.6.
Average extent of oscillation: 33% of a tone, A.D., .075.

[10] Attention is called to the narrow extent of this agitated sounding tone, showing that other factors besides extent of vibrato oscillation contribute to the agitated quality.

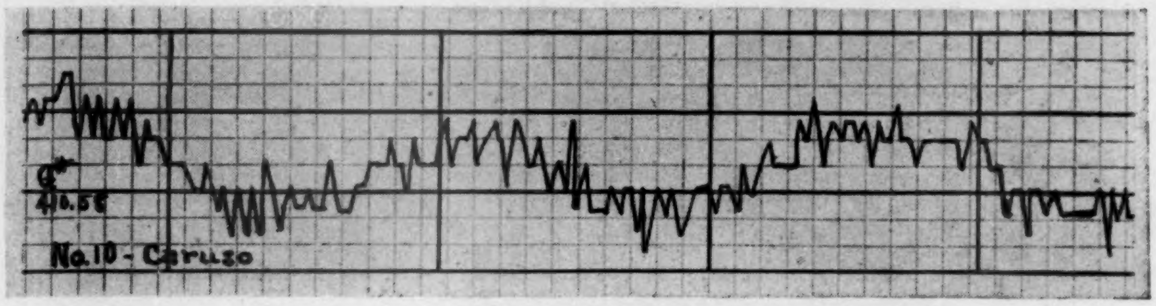


FIG. 10. Tenor: Caruso.

Selection: "Largo" (Handel) from "Xerxes," Victor Record No. 6023-A.
Emotion: agitated.
Vowel photographed: Italian "a."
Location in selection: highest tone in the opening recitative.
Standard pitch nearest the tone sung: G♯ 410.58.
Mean frequency of the tone sung: 410.51.
Average vibrato cycle-length: .144 sec., A.D., .014.
Rate of vibrato oscillation: 6.9 per sec.
Average extent of oscillation: 43% of a tone, A.D., .053.

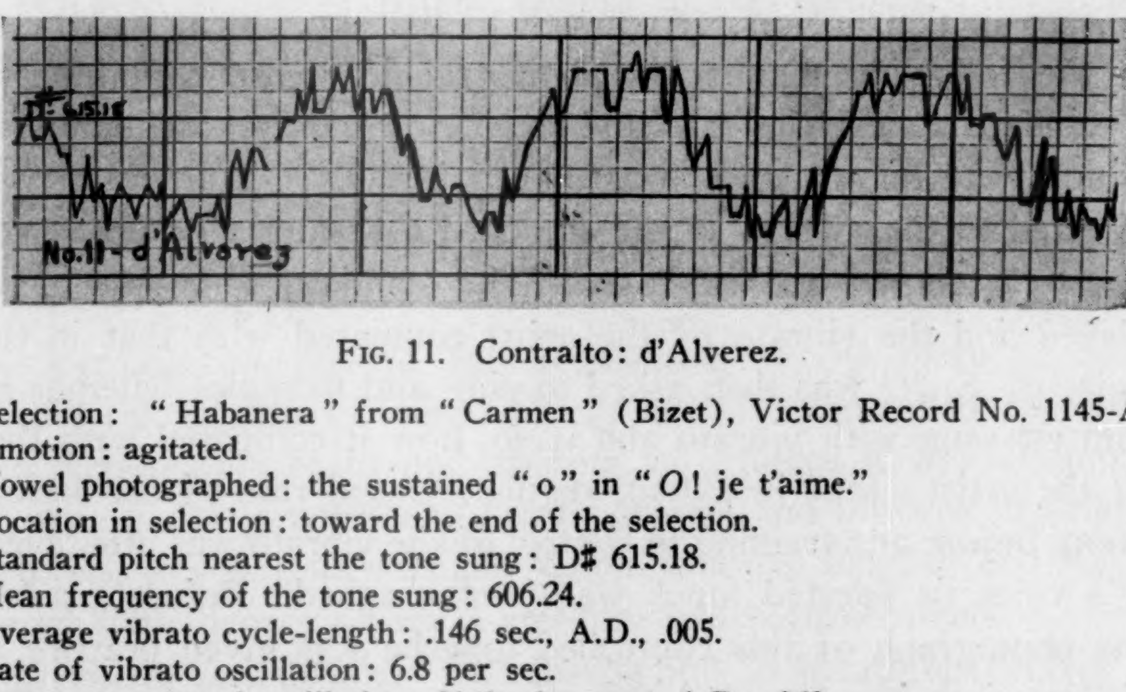


FIG. 11. Contralto: d'Alverez.

Selection: "Habanera" from "Carmen" (Bizet), Victor Record No. 1145-A.
Emotion: agitated.
Vowel photographed: the sustained "o" in "*O*! je t'aime."
Location in selection: toward the end of the selection.
Standard pitch nearest the tone sung: D♯ 615.18.
Mean frequency of the tone sung: 606.24.
Average vibrato cycle-length: .146 sec., A.D., .005.
Rate of vibrato oscillation: 6.8 per sec.
Average extent of oscillation: 81% of a tone, A.D., .060.


FIG. 12. Contralto: d'Alverez.

Selection: "Habanera" from "Carmen" (Bizet), Victor Record No. 1145-A.
Emotion: agitated.
Vowel photographed: "a" in "toi."
Location in selection: last tone of the opening recitative.
Standard pitch nearest the tone sung: D 290.33.
Mean frequency of the tone sung: 296.82.
Average vibrato cycle-length: .169 sec., A.D., .005.
Rate of vibrato oscillation: 5.9 per sec.
Average extent of oscillation: 1.04% of a tone, A.D., .071.

*Method of using "standards" as models.* *E* found that many of the *O*s seemed to be unaware of the presence or lack of vibrato in their voices. Approach to the experiment was made in the following manner: a phonographic record containing a "standard tone," the rate and extent of vibrato oscillation of which were known to *E*, was played for *O*. *O*'s attention was directed to the vibrato in the standard tone and a graph of the tone was shown and explained. The standard tone was again played and the vibrato of the artist compared with that in the voice of *E*. *O* was then asked to sing and to notice whether he himself sang with vibrato and if so, how it compared with that of the artist's tone in extent, regularity, and rate of oscillation. Next, before any training in control of the vibrato was attempted, *O*'s voice in selected tones was photographed. Before making the photograph of this controlled tone he was given practice in singing into the horn of the phonophotographic camera. The pitch for all tones in the study was taken from a 435 d.v. tuning-fork. The *O*s were, in every case, told to make as good, smooth tones as possible while intoning the sentence, "The night is clear and calm," sustaining the vowel of the word "calm" until told to "stop." The phonophotographs of these tones represent tones about .75 sec. in length.

After *O* had been shown in a graph the discrepancies in rate,

regularity, or extent of oscillation between the vibrato in his own voice and that of the standard tone of the artist, the training proper began.

*Control of amount and character of training.* Since this study has in the main been carried on with the private vocal students of the writer, the subject of control of the vibrato was deferred from the third to the twentieth lesson depending upon the state of advancement of the student and his attitude toward the experiment. The length of the training period for improvement in control of the vibrato varies therefore as is shown in the tables of Part III from a few days to several weeks. In no case, however, are results shown which required a training period longer than a semester of eighteen weeks.[11] Only five of the vocal students had metronomes; the others confined the checking of improvement in the rate to time taken in their regular weekly or semi-weekly lesson periods.

One of the most potent factors in the training in all cases seemed to be the incentive gained from the objective evidence shown by the control phonophotograph of the faults to be overcome, and the evidence in subsequent tests that improvement was being made.

## PART II. METHODS OF TRAINING.

*Methods and media for production of the vibrato.* Since beautiful vibrato is impossible in a badly controlled voice, no correction of vibrato nor training to produce it was attempted before giving attention to breath control and practice in singing vowels, words, sentences and simple songs in English and Italian until some degree of vocal freedom had been obtained.

*General instructions.* For instruction in breathing control all *O*s, with the exception of the pre-adolescent boys who took part in the experiment, were shown pictures of the diaphragm and its action in respiration explained. The following practical advice on "How to Breathe" was read to all adult *O*s: (5)

[11] In the case of three *O*s, photographs taken at the end of the training period were unsuccessful, which necessitated the taking of another final photograph at a later date. The training period, however, was not continued beyond the eighteen weeks' limit.

"Long phrasing depends, as stated earlier, not on the large amount of breath taken in, but on the small amount given out. It is but common sense to say that the economic control of breath should be given to the part of the body which has the necessary muscles to assume it. There is exactly such a muscle in the center of the body, ready and willing for the work, and capable of developing unlimited powers of expansion and gradual relaxation. It works in conjunction with other great muscles in the center of the body. What its name is does not matter a straw; let us call it the 'breathing muscle' and proceed to place it.

"Run your hand down your breastbone till you come to the end. Where it stops the ribs branch off on either side. In the triangle between those ribs, with the apex at the end of the breastbone, there is a muscle which in its potentialities for breath-control is most remarkable. It is in the exact center of the body, and when developed not only gives control of exhalation but, with its friendly mates, supports the most important internal organs.

"Now raise the chest—then breathe in (through the nose, whenever there is time) slowly. As you breathe *in*, the breathing muscle should expand *out*. (The beginner, from sheer 'cussedness,' has a tendency to do the opposite and, as he breathes in, to contract the muscle. This is fatal. He should keep his fingers pressed against the breathing muscle and, as he breathes *in*, should feel and see the muscle push his fingers *out*). When the lungs are full and the muscle expanded as far as it will go, hold all taut in *status quo* for an appreciable time; then press gently with your fingers on the muscle, and breathe out as slowly as ever you can, holding the breath back and relaxing the muscle by the slowest possible degrees. As the breath goes *out*, the muscle contracts *in*.

"The training of that muscle to regulate its *relaxation* at the singer's will is the foundation on which singing is built."

The device of blowing a "warm breath" on the hand while sustaining tones or singing scale passages was used with all *O*s. This was done to call attention to the abdominal musculature which is brought into play by forced expiration, and as a check on whether or not the instructions contained in the foregoing paragraph on "How to Breathe" were being carried out.

The following paragraphs on control of the lips, tongue and jaw in singing were also read: (2)

"The tip of the tongue should habitually rest against the under front teeth (during the production of vowel sounds).

"The upper lip plays the most active part in the shaping of the vowels. It should never be drawn against the teeth when producing tones; indeed, there should be often a little space between the upper lip and the teeth so that the vibration of the sound-waves can have free play."

Also the following paragraph in regard to use of the under jaw: (2)

"A relaxed under jaw allows freer action of the vocal cords and ampler resonance. The under jaw should drop little by little as the voice ascends the scale, thus opening the mouth slightly wider with each rise in the pitch of the tone . . . at the highest pitch of the poice the mouth should open to its full width. At the same time, care should be taken *not* to draw the corners of the mouth back as in smiling, because this lessens the resonance, and gives the tone a flat sound."

Also the quotation: (3)

"The vibrations of the voice should always be 'tasted' in the front of the mouth—not gargled in the throat. The tongue, tradition to the contrary, should not be grooved for the production of vowel sounds but should be bunched forward in the mouth with the tip resting against the lower front teeth. This leaves the throat open without yawning or other device, while dropping the jaw opens the front of the mouth and provides additional resonating space."

Throughout the training, imitation of the vibrato in the "standard" phonographic tones was encouraged. In three cases, *O*s bought the "master" records that they might hear them more frequently on their phonographs at home.

In the case of the pre-adolescent boys and with adults of both sexes, who seemed unable to learn to produce the vibrato, either by conscious or unconscious imitation, a "panting exercise" was resorted to in order to establish a rhythmic period in the synergic or alternate contraction and relaxation of muscles having to do with the action of the diaphragm in expiration. This voiceless pulsation of the out-going breath and of the diaphragm being established, *O* was next asked to sustain a tone maintaining the same rhythmic control of the breath.

While the most of this preliminary training was confined to sustained tones on various pitches of the middle voice, considerable practice was given in slow singing of scale passages using various vowel sounds. In this exercise, *O* was asked to sing 1, 2, 3, 2, 1 or 1, 2, 3, 4, 5, 4, 3, 2, 1, of the scale while producing an equal number of pulsations of the vibrato on each scale tone. Gain in these exercises was followed by the intoning of short, meaningful sentences in the middle voice. The sentences used for this purpose were chosen from the following: "I sing a song of joy!", "My heart is glad today!", "The sun is clear and bright!", "The night is dark and drear!", "The night is calm and cool!", "The sea is deep and calm!", "The night is clear and calm!" The last sentence enumerated was the one invariably used for photographing the vibrato in tones of the vocal students taking part in the experiments.

Simple, sustained songs of moderate range in English and Italian were next sung with special attention at first to regularity of the vibrato and its presence in all sustained tones. Thus

the periodic oscillation of the vibrato was established in cases where the control tone showed no vibrato. It was found that in most cases turning the head very slowly to right or left while producing sustained vowel sounds tended to relieve tension of interfering muscles in the neck and to make the vibrato more regular. Periodic oscillation being set up in the tones of the *O*s, the work of refinement of the vibrato in regard to the rate and extent of oscillation was next instituted.

*Metronome technique for the control of rate of oscillation.* In checking the vibrato with the metronome to find its rate, the phenomenon known as " subjective rhythm "—the tendency of the ear to supply accent to a regular succession of sounds—was found to be of great assistance. As in the training for control of pitch the visual stimulus supplied by the tonoscope aids *O* in the reproduction of pitch, so the auditory stimulus ~~supplied~~ by the metronome was found to act " both as a whip and a guide to specific effort " (**12**, p. 197) in control of the regularity and rate of the vibrato.

In the initial test of the vibrato with the metronome for rate, 83 per cent of the *O*s in this study who had vibratos chose a subjective rhythm of 4's—four beats of their vibrato to each click of the metronome; 7 per cent chose a subjective rhythm of 3's; and 10 per cent for various reasons were at the first trial unable to check their rates with the metronome. For the initial test, in every case *E* asked *O* to sustain a tone in the middle voice. While *O* was singing the tone, *E*, using a subjective rhythm of 4's, adjusted the metronome to the approximate rate of the vibrato in *O*'s tone and said, " Let us see whether your vibrato is with the metronome." In case of the group who were unable to check their vibratos at the first trial, *E* suggested a rhythm of 4's and proceeded by this means to " harness " *O*'s vibrato to the rhythm set up by the metronome. In order to do this a " stepping and hand-fanning exercise " was resorted to. This was done by having *O* step at each click of the metronome while fanning with the hand in a rhythm of 4's. Hand-fanning in 4's by *E* with or without the metronome was also used freely in training *O*s to increase or diminish their rates.

All of the *O*s who were able to check the rate of their vibratos by the metronome were also able to vary the rate to some degree, both faster and slower than the one to which they had become habituated. The *O* having the greatest range of rate in singing with the metronome being C. H., whose phonophotographs show a gradual increase in rate from 4.4 to 7.7 oscillations per second (Part III, Fig. 15); and whose extent of oscillations throughout compares favorably with that found in "standard tones" of Marsh, Dadmun, Murphy and Chaliapin chosen as examples of refined vibrato. Graphs made from phonophotographs of *E*'s voice, Fig. 13, also show a range of rate in following the metronome of from 4.4 to 6.2 oscillations per second. Owing to the fact that a rate of under five oscillations per second is considered undesirable, it was thought inadvisable to train others of the student *O*s to sing with so slow a rate.

In case that *O* had an established habit of too slow a vibrato on a plateau of say 4.5 pulsations per second, it was usually found to be impossible for him to follow the metronome at the faster rate of 5.5 or 6 at the beginning. As shown by the evidence submitted, however, by practice covering a period of from one to eighteen weeks, the desirable rate of between six and seven oscillations per second was usually attained.

Reports of *O*s who were able to follow the metronome with their vibratos are unanimous to the effect that they had but to control the breath deeply with muscles in the region of the diaphragm, as described in "How to Breathe," quoted in a former paragraph, and to pay attention to the rhythm set up by the metronome.

Table I shows the metronome markings used with their corresponding rate computations using a subjective rhythm of 4's, four beats of the vibrato for each click of the metronome.[12] In this connection it may be stated that the metronome used in this study was checked by the writer and two other persons by counting in three and five minute intervals and the various markings

[12] Since metronome 63 means 63 clicks of the metronome per minute, if the observer's vibrato using a subjective rhythm of 4's follows the metronome at this speed, it is seen that his rate of vibrato is 252 oscillations per minute or 4.2 oscillations per second.

used in the experiment were verified or corrected. Both original and corrected markings are given to avoid confusion on the part of the reader or of anyone who wishes to repeat the experiment.

TABLE I. *Showing corrected metronome markings and rate computations used in this study*

| Metronome Marking | Corrected Marking | Rate |
|---|---|---|
| 63 | 61.2 | 4.1 |
| 66 | 64.0 | 4.3 |
| 69 | 68.0 | 4.5 |
| 72 | 71.0 | 4.7 |
| 76 | 74.0 | 4.9 |
| 80 | 79.0 | 5.3 |
| 84 | 82.4 | 5.5 |
| 88 | 87.4 | 5.8 |
| 92 | 91.0 | 6.1 |
| 96 | 94.2 | 6.3 |
| 100 | 98.0 | 6.5 |
| 104 | 102.2 | 6.8 |
| 108 | 106.0 | 7.1 |
| 112 | 110.0 | 7.3 |
| 116 | 114.0 | 7.6 |
| 120 | 118.0 | 7.9 |
| 126 | 123.7 | 8.2 |

In singing with the metronome for control of rate, all *O*s were instructed to keep the rhythm subjective; to avoid accenting with the voice, to " sing on a line," and to make the vibrato as regular as possible. Objective accenting of the rhythm with the voice was found to show on the graphs in a periodic increase in extent of the vibrato cycles falling on the accent. That this effect was usually avoided, however, is shown by an examination of the graphs of final tones of *O*s found in Part III of this study.

*Phonophotographic technique for control of extent of oscillation.* As stated in Part I, in all cases the subject of control of the vibrato was approached by observations of " standard tones " from one or more of the phonographic records selected for this purpose; and specific training in control was begun after the *O*s' voices had been photographed.

*Apparatus and technique used.* The type of phonophotographic apparatus referred to in the introduction as the " studio type " was used in this experiment in photographing directly from the voice. In this apparatus a phonographic motor is used for revolving the moving picture film. A turn-table, 1285 mm. in cir-

cumference, constructed of two-inch plank with a flange to carry the moving picture film, was placed on the turn-table of the phonograph. On the under side of the plank turn-table there was a trigger which caused a click at each revolution. This click served the double purpose of notifying *E* of each revolution of the film, and in recording the speed of the motor. The speed was checked with a metronome set at 80 r.p.m.

When no time-line device is used it becomes imperative that the film travel at a constant known speed. *Seashore* (12, p. 171) shows that when a phonograph motor of "one of the standard makes in good condition is run within its normal range of speed, and wound to a moderate tension, it runs with an error of less than one-thousandth of a second per revolution," which was considered more than sufficiently accurate for the purposes of this study. In all cases, however, to guard against changes in temperature, over-tension in winding, *etc.*, the motor was caused to run until it clicked synchronously with the metronome for ten revolutions before a picture was taken. The phonophotographic apparatus was set up in a large dark closet opening into *E*'s vocal studio.

*Reading of films.* The films taken by the writer with the apparatus just described were read by the wave-length method in terms of .1 mm. The known speed of the film being metronome 80 r.p.m. (79 r.p.m. corrected marking) the speed of the film per second is computed as in the case for the apparatus described in photographing from phonographic records. The size of the turn-table of the writer's apparatus being smaller (1285 mm.) than that of the one used in the labortory of the University of Iowa (1961 mm.) and the speed at metronome 80 slightly faster than that at which the phonographic records were made, a new work-table or scale for converting wave-length into frequencies had to be worked out.

*Types of observers.* The following general types of *O*s took part in the experiments of this study: (1) Adults of both sexes having (a) a continually fast rate, and (b) a continually slow rate of vibrato oscillation; (2) Adults of both sexes having (a) a continually wide, and (b) a continually narrow extent of

vibrato oscillation; (3) Adults having unusual control of vibrato; (4) (a) Pre-adolescent boys having no vibrato, and (b) adults of both sexes having no vibrato.

## PART III. DATA

*Experiment No. 1-A: in learning to control rate of vibrato oscillation.* Working from the theory that the vocal vibrato is produced by muscular action, and possessing a naturally slow rate of oscillation in his own vibrato, the writer tried the first experiment on himself. Having observed in teaching that slow vibratos are often quickened somewhat in the interpretation of songs which move at a rapid tempo, the suggestion came that possibly rhythm might be used to advantage in teaching control of the rate and regularity of vibrato oscillation.

After trying a device with the table of a phonograph arranged to produce 5, 6 and 7 clicks per second, it was decided that this measure was too coarse. The "metronome technique," however, described in Part II seemed to be effective in helping *E* to increase his own rate. Through practice he was able to sing with the metronome using a subjective rhythm of fours from metronome 69 to 92, making a range in rate of vibrato oscillation of from 4.5 to 6.1 oscillations per second.[13] Slower or faster than the rates mentioned his vibrato refused to go, giving rise to the supposition that a possible physiological limit had been reached. By strenuous practice *E*'s vibrato had been made to follow the metronome at 100 and 104, although his rates for these markings have not been objectively verified.

The series of graphs in Fig. 13 from phonophotographs made in the psychological laboratory of the University of Iowa, shows the voice of *E* (A.H.W.) while singing with the metronome. An examination of Table II comparing the rates shown in Fig. 13, Nos. 1 to 6 inclusive, with the corrected metronome mark-

[13] *E* was encouraged in the belief that the vibrato could be controlled through rhythm, by observations made by Professors Whitley and Ruger of Teachers College, Columbia University, and by the successful outcome of an experiment performed by the writer in a seminar of eighteen graduate students of that institution, when one of the instructors acted as *O* in singing with the metronome over a wide range of rates.

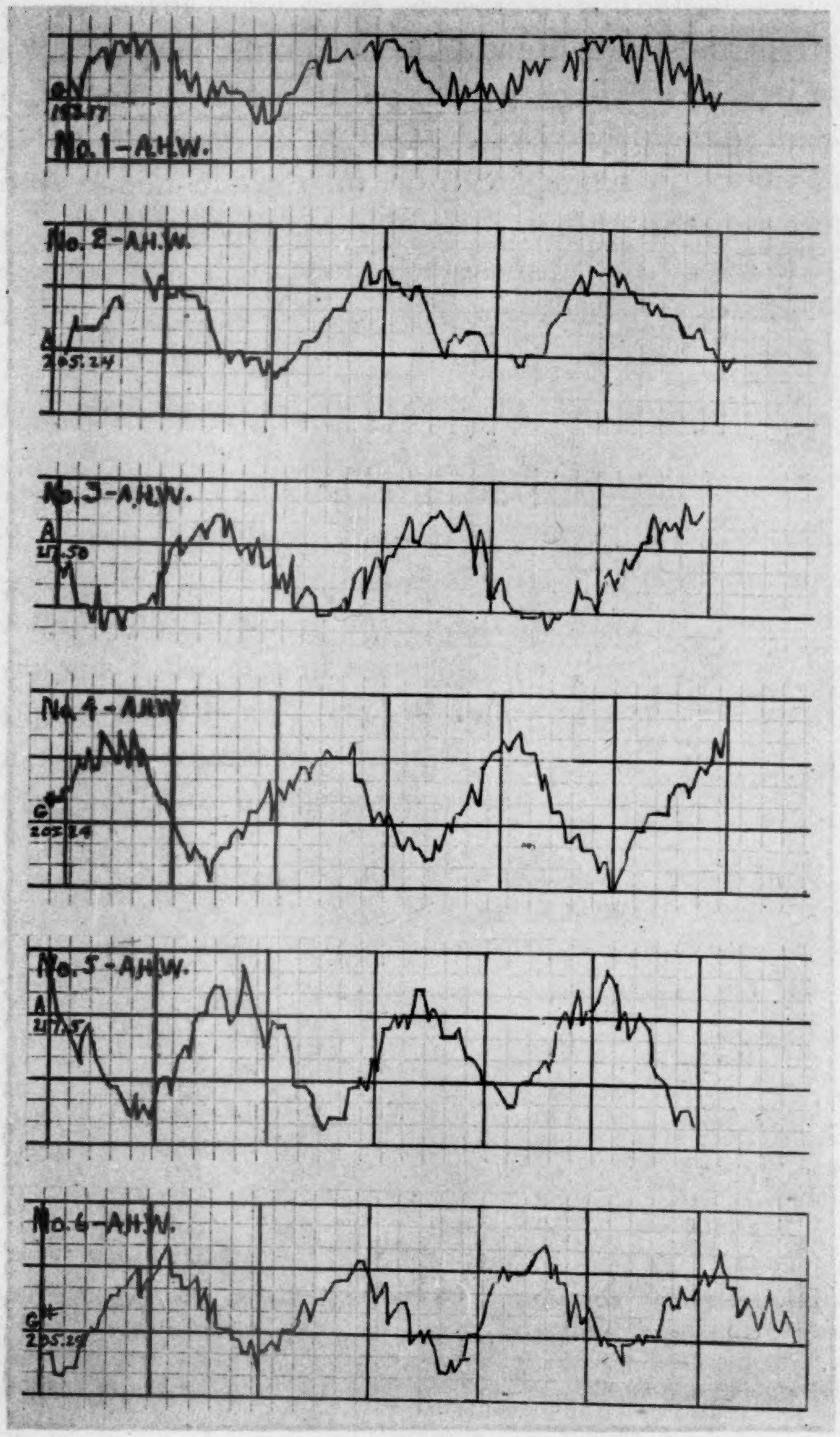


FIG. 13. Data shown in Table II.

The progressive increase in rate from graph to graph in the first four graphs of this series is shown in the gradual drawing together of the vibrato oscillations. The last three graphs of the series show no increase regardless of faster metronome markings, showing that *O* had reached his maximum rate.

ings, Table I, Part II, seemed to show sufficient correspondence to warrant the use of this technique for the purpose for which it was intended. This latter supposition was borne out by the results of Experiment No. 2 (C.H.), showing unusual control of the vibrato in singing with the metronome, and later by observations of the student *O*s in the experiments for the control of rate to the effect that the establishment of a subjective rhythm was helpful to them in learning to control the rate and regularity of vibrato oscillation.

*Experiment No. 1-B: in learning to control extent of vibrato oscillation.* Fig. 14, graphs Nos. 1 to 5 inclusive, were made from phonophotographs taken after the results of the first series were known. The second series was intended to show that by focusing attention on " How to Breathe " as outlined in " General Instructions " in Part II, the extent of oscillation could be decreased simultaneously with increase in rate when singing with the metronome. See Tables of Results: II and III corresponding to Fig. 13 and Fig. 14 for detailed information as to rate and extent of oscillation of tones photographed in this experiment.

TABLE II. *Results: experiment No. 1–A in learning to control rate of vibrato oscillation, shown in graphs of Fig. 13*

| | Sung at Metronome | Ave. Ext. Oscil. in % of Tone | A.D. | Ave. Vib. Cyc. l'gth in .01 sec. | A.D. | Rate Oscil. per sec. | Rate Compt'd on Cor. Met. Mk. |
|---|---|---|---|---|---|---|---|
| No. 1 | 69 | .38 | .022 | .228 | .017 | 4.4 | 4.5 |
| No. 2 | 72 | .48 | .025 | .207 | .006 | 4.8 | 4.7 |
| No. 3 | 76 | .52 | .075 | .197 | .002 | 5.1 | 4.9 |
| No. 4 | 92 | .66 | .072 | .162 | .021 | 6.2 | 6.1 |
| No. 5 | 100 | .62 | .023 | .165 | .007 | 6.1 | 6.5 |
| No. 6 | 104 | .50 | .000 | .164 | .006 | 6.1 | 6.8 |

TABLE III. *Results: experiment No. 1–B in learning to control extent of vibrato oscillation, shown in graphs of Fig. 14*

| | Sung at Metronome | Ave. Ext. Oscil. in % of Tone | A.D. | Ave. Vib. Cyc. l'gth in .01 sec. | A.D. | Rate Oscil. per sec. | Rate Compt'd on Cor. Met. Mk. |
|---|---|---|---|---|---|---|---|
| No. 1 | 92 | .46 | .088 | .102 | .102 | 6.0 | 6.1 |
| No. 2 | 80 | .30 | .032 | .185 | .004 | 5.4 | 5.3 |
| No. 3 | 84 | .40 | .000 | .181 | .008 | 5.5 | 5.5 |
| No. 4 | 88 | .29 | .037 | .174 | .007 | 5.7 | 5.8 |
| No. 5 | 92 | .35 | .050 | .165 | .011 | 6.1 | 6.1 |

*Experiment No. 2: showing unusual control of the vibrato by Observer C.H.* C.H., baritone, a talented musician, blind from birth, volunteered to be an *O* in this experiment. He reported that he used to have a "straight voice," but that he had de-

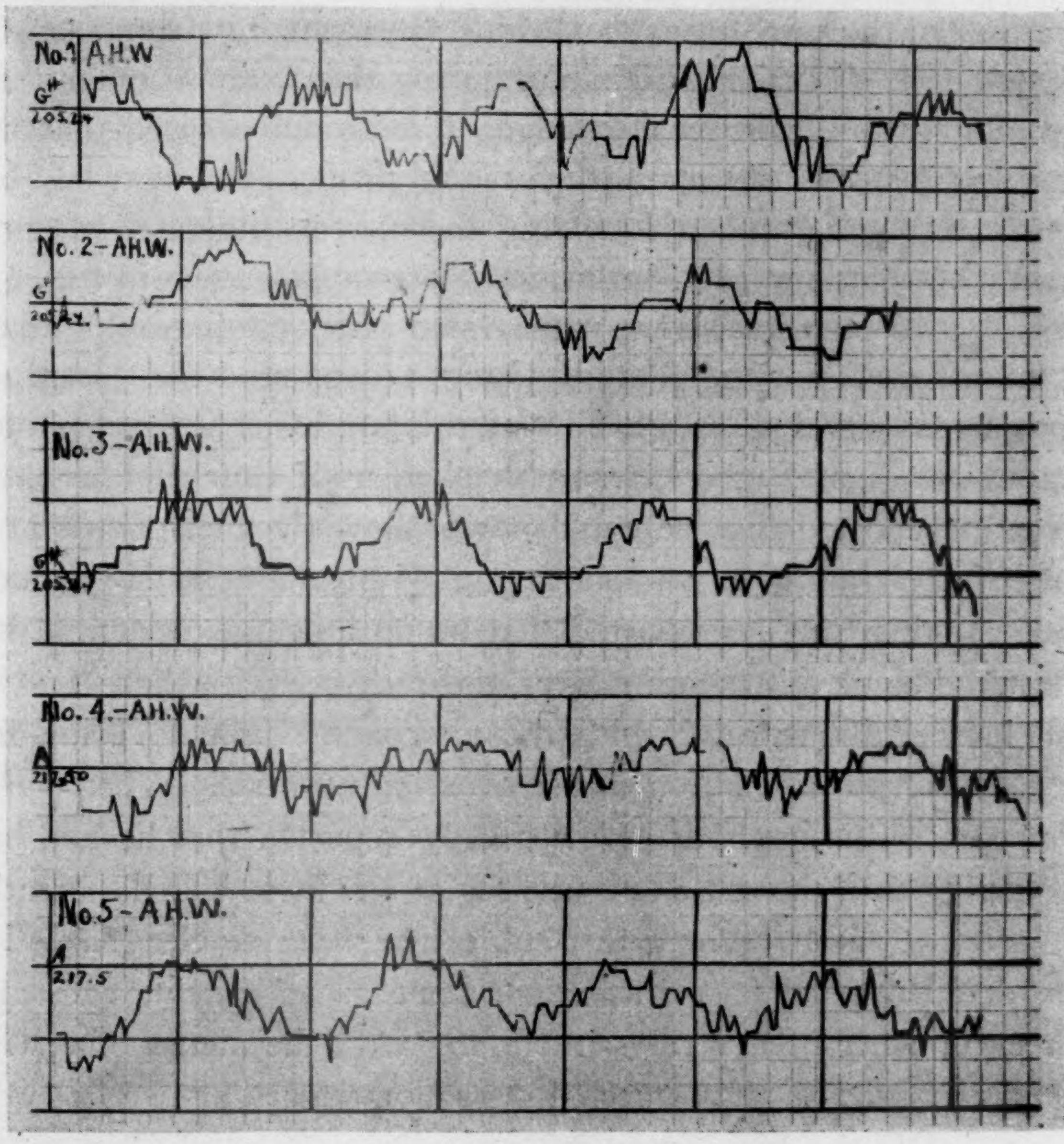


FIG. 14. Data shown in Table III.

Graph No. 1, Fig. 14, was made from a phonophotograph, taken as a test for rate and extent of oscillation, one week before the other four tones of this series were photographed. Graphs Nos. 2 to 5 show that extent may be decreased simultaneously with increase in rate. (See text and Table III for further data.)

liberately cultivated the vibrato after listening to his favorite artists on the phonograph and noticing that his voice was different from theirs. He also reported that when asked to sing

over the radio his rate of oscillation frequently became too slow, and that he did not know what to do to quicken it. He at once became interested in the "metronome technique" for control of rate and when asked to sing with the metronome, chose a subjective rhythm of fours and followed with his vibrato while *E* adjusted the instrument to various rates ranging from met. 69 to met. 104. *O* made no remarks during this exercise other than the observations with each change of metronome speed that the rate was faster or slower as the case might be. The next day his voice was photographed following the metronome rates ranging from met. 69 to met. 104 inclusive. The graphs shown in Fig. 15, Nos. 1 to 6 inclusive, were made from phonophotographs taken at this time. After the photographing, *O* was read the "Instructions to Observers" in Part II of this study. The final photograph, No. 7 of Fig. 15, was not taken until four months later when *O* reported that he could now follow the metronome at a much faster rate. He was photographed on the next day at met. 116. At this time he reported that he no longer experienced his former difficulty in singing over the radio or elsewhere for he had learned by working with the metronome how to bring his rate of vibrato oscillation under conscious control. When questioned as to his methods of control, he reported that he had but to "string up" the muscles in the region of the so-called "breathing muscle" and follow a fast subjective rhythm. See Table IV for detailed results of this experiment as to extent, rate and correspondence of *O*'s rates in singing with the metronome with rates computed on the corrected metronome markings.

TABLE IV. *Results: experiment No. 2 showing unusual control of vibrato. Observer C. H.*

| | Sung at Metronome | Ave. Ext. Oscil. in % of Tone | A.D. | Ave. Vib. Cyc. l'gth in .01 sec. | A.D. | Rate Oscil. per sec. | Rate Compt'd on Cor. Met. Mk. |
|---|---|---|---|---|---|---|---|
| No. 1 | 69 | .35 | .025 | .227 | .007 | 4.4 | 4.5 |
| No. 2 | 72 | .35 | .000 | .203 | .005 | 4.9 | 4.7 |
| No. 3 | 80 | .38 | .024 | .198 | .000 | 5.5 | 5.3 |
| No. 4 | 88 | .29 | .058 | .169 | .005 | 5.9 | 5.8 |
| No. 5 | 100 | .30 | .050 | .150 | .007 | 6.7 | 6.5 |
| No. 6 | 104 | .24 | .044 | .146 | .017 | 6.8 | 6.8 |
| No. 7 | 116 | .34 | .043 | .130 | .010 | 7.7 | 7.6 |

*Experiment No. 3: training pre-adolescent boys to produce vibrato.* Vibrato in the untrained pre-adolescent boy's voice is

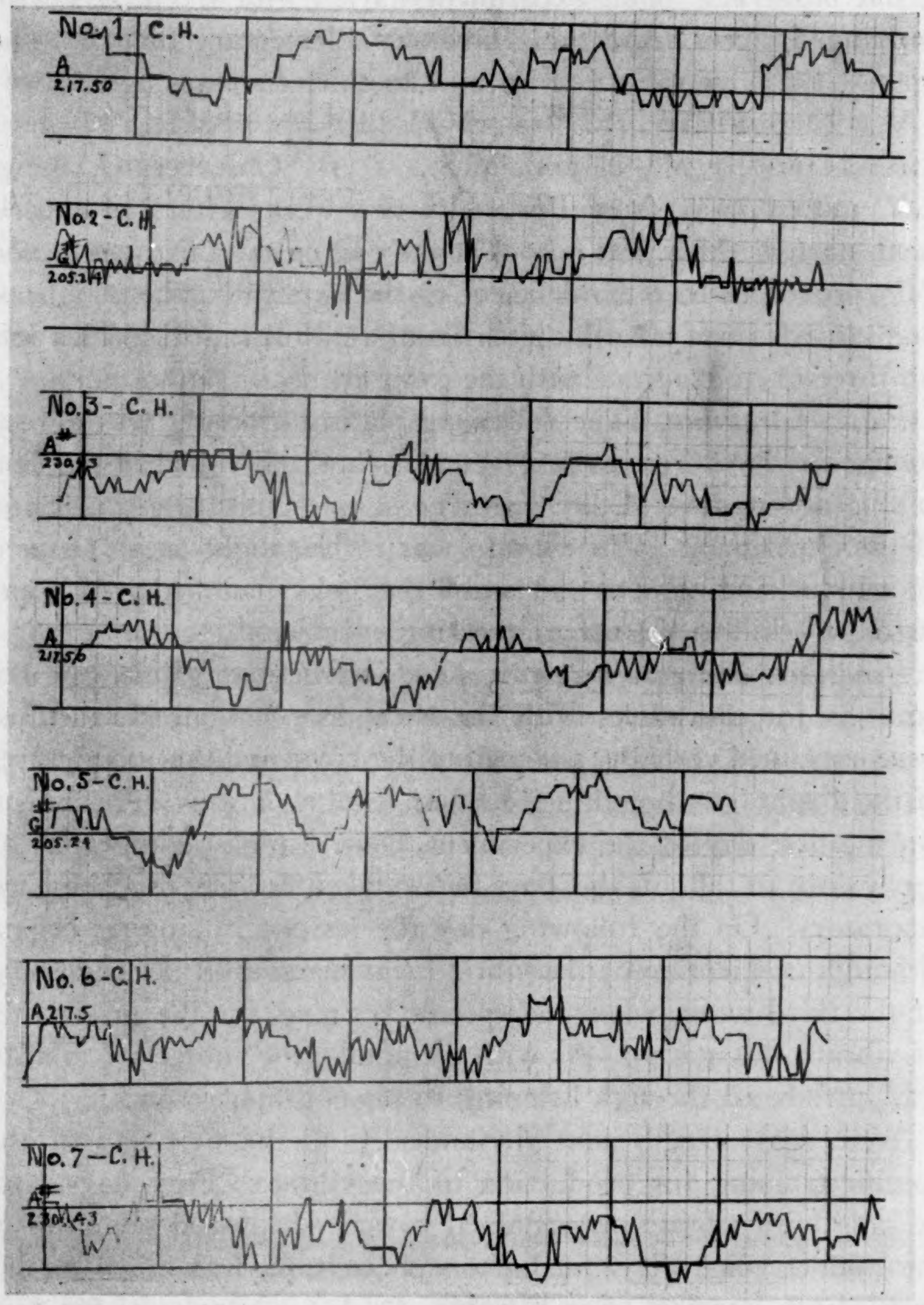


FIG. 15. Data shown in Table IV.

very rare. During fifteen years of experience as a public school music supervisor, the writer observed but one case. For this

reason it was thought best to use a group of pre-adolescent boys to determine whether or not the vibrato can be directly taught.[14]

*The observers.* This experiment started with seven boys with unchanged voices from the University Elementary School. The ages of the boys ranged from nine to thirteen years as follows: G.V., 9 yrs.; E.V., 12 yrs.; V.P., 10 yrs.; W.R., 13 yrs.; R.A., 11 yrs.; F.M., 11 yrs.; M.S., 12 yrs. Observers G.V. and E.V. moved away from Iowa City two weeks after the experiment started. M.S. left school at the end of the third week, and V.P. proved to be pitch deficient to the extent that he could not sing *America* nor take the pitch from a 435 d.v. fork. This left but three *O*s to continue with the experiment.

*Plan of training.* The following plan of training was agreed upon. The boys were to be given class and individual instruction in singing one hour a day, five days a week until the conclusion of the experiment. The vibrato was to be taught as an element in artistic singing, but not until the boys had acquired some degree of skill in the use of the singing voice.

*Procedure and case histories.* The instructions given were the same as for the adults with the exception that all instructions were explained verbally, not read to the boys, and that no pictures of the diaphragm, breathing or other vocal apparatus were shown. On the first day of the experiment, control tone photographs of the voices of all of the boys were taken in the psychological laboratory. On the following day the lessons in singing began, although no mention of the vibrato was made until the beginning of the third week, when the specific training for the production of vibrato was started. As with the adults, the subject of vibrato was introduced through listening to phonograph records.

W.R. was able to pant rhythmically on the first day of the specific training for production of the vibrato. Four days later he sang with vibrato on sustained vowels of intoned sentences in the middle voice. His final phonophotograph was taken on his thirty-sixth lesson.[15] See Fig. No. 16-A for graphs of his con-

[14] Rarity of vibrato in the voices of pre-adolescent boys is also borne out by *Metfessel's* (**8**) recent studies of the vibrato.

[15] On the day that the specific training for the production of vibrato began. W.R. reported that he had, sometime during the previous year, received some

trol and final tone, and Table V for detailed record of the experiment.

F.M. was able to pant rhythmically on the first day of the specific training; on the seventh lesson period thereafter he was able to sing *America* with vibrato. The final phonophotograph was taken on his twenty-first lesson period after the specific training was introduced. He was present thirty-one periods during the experiment. See Fig. 16-B and Table V of Results.

R.A. could not pant rhythmically until the fifth lesson after the subject of vibrato training was introduced. Five periods later he began to show a little vibrato in his tone. His final phonophotograph, made on the twenty-first day of specific training, was a failure for technical reasons and had to be retaken at the beginning of the following summer. The graphing of the readings from this film show an average extent of oscillation of .52 per cent of a tone.[16] Since theoretically this extent might be considered rather wide for calm singing, it was *E*'s intention at the beginning of the third summer to make this correction. The plan was all the more feasible since the boy's voice had not yet changed. Phonophotographs taken on four successive days, at this later time, however, showed an average extent of .33 per cent of a tone; therefore no further correction was considered necessary. See Table V for detailed results of this experiment and Figure 16-C showing graphs of the *O*'s control and final tones.

TABLE V. *Results: experiment No. 3, in training pre-adolescent boys to produce vibrato*

| *Os* | Control Tones | Total Per'ds Instr. | Final T. Ave. Ext. Oscil. in % of Tone | A.D. | Final T. Ave. Cyc. L'gth in .01 sec. | A.D. | Final T. Rate Oscil. per sec. |
|---|---|---|---|---|---|---|---|
| W.S. | No Vib. | 35 | .366 | .022 | .150 | .008 | 6.7 |
| F.M. | No Vib. | 31 | .470 | .043 | .173 | .010 | 5.8 |
| R.A. | No Vib. | 31 | .520 | .076 | .165 | .015 | 6.0 |

instructions from Dr. Metfessel in regard to production of the vibrato, but that he had forgotten the instructions. The latter part of his report was verified by the fact that his controlled tone phonophotograph shows no vibrato, and that no vibrato was detected in his tones during the two weeks of preliminary training.

[16] This film was of necessity read by the "time-line method," which accounts for its somewhat smoothed appearance as compared with other graphs of the series.

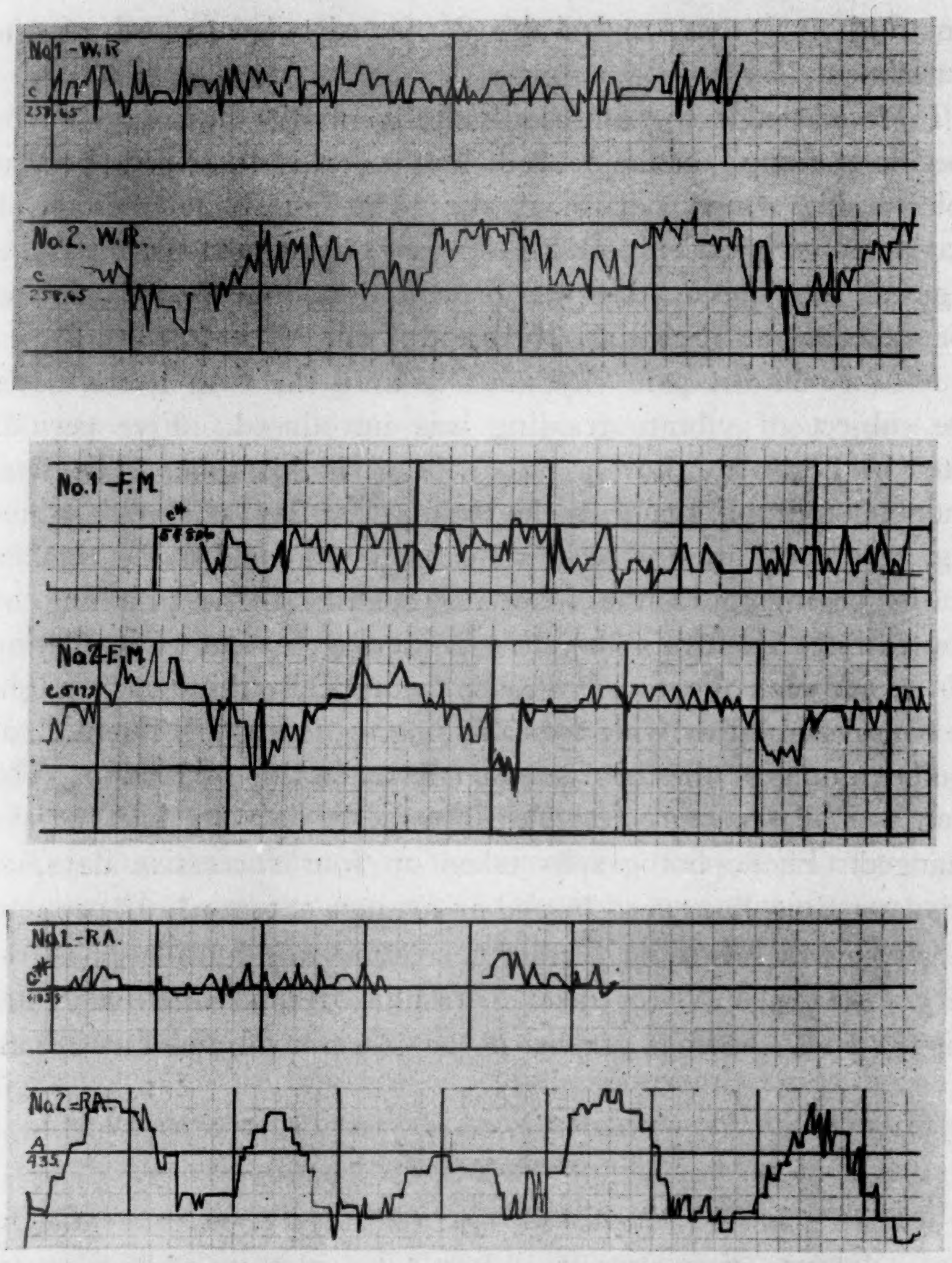


FIG. 16. Controlled tone and vibrato of W.R., F.M., and R.A.

*Experiment No. 4: in teaching an adult to produce vibrato. Observer H.M.W.* H.M.W., baritone, a graduate student in the department of psychology at the University of Iowa, was *O* in this experiment. He had had some lessons on the piano and was keenly interested in music as an art from the point of view of æsthetics, but had not studied voice. His controlled tone phonophotograph, see Fig. 17, No. 1, showed a remarkably pure tone

without vibrato. *O* reported that he had never sung with vibrato and that he had probably developed the pure "head quality" of tone from singing into the various laboratory instruments for the measurement and reproduction of pitch, where a pure tone, without vibrato, is an asset.

*O* was to receive a half-hour of instruction every day, five days a week throughout the training period. On the first day of instruction he reported that he was doubtful about his ever being able to produce the vibrato. Despite his negative attitude toward the outcome of the experiment, however, he showed himself to be unusually apt in learning to follow "General Instructions" in Part II. On the third instruction period he discovered how to

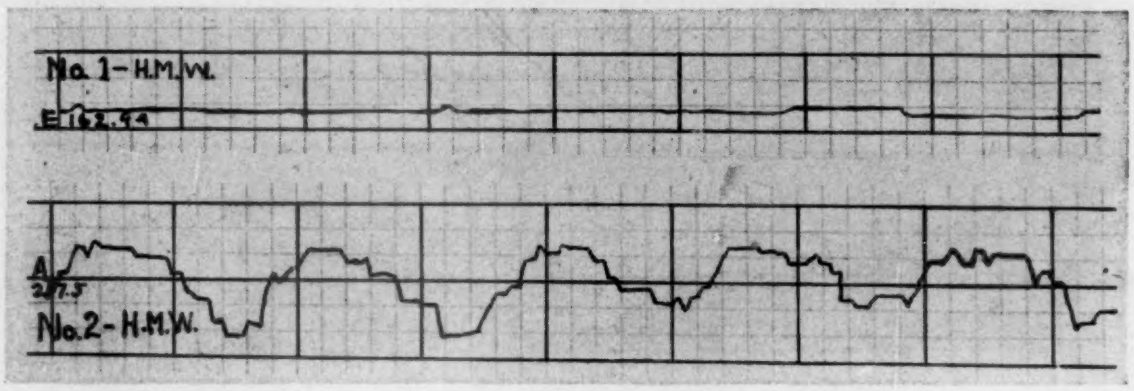


FIG. 17. Controlled tone and vibrato for H.M.W.

produce a very fast vibrato in a tone which lacked power. He reported that this vibrato was controlled by the muscles of his throat. He was shown, thereupon, through the "warm breath device" how to shift the control of the vibrato more to the abdominal musculature. This resulted in a tone of more resonant character and in a slower rate of vibrato oscillation. On the tenth instructional period he was able to follow the metronome from met. 80 to met. 88. In checking his vibrato for rate he chose a subjective rhythm of fours. On his fifteenth instruction period he followed the metronome at met .84 to met .92. At this time he reported that in his opinion the rhythm was a very effective factor in control not only of the rate, but of the regularity of his vibrato oscillation.

The final photograph, taken on his twentieth instruction period was a failure due to technical reasons and was retaken five

months later. In forwarding the film of his final tone to the writer, he volunteered the report that, while his rate of oscillation from lack of practice had slowed down considerably, his vibrato had become automatized to the extent that it now seemed unnatural to him to sing without it. The graph of the final phonophototgraph shows an extent of pitch oscillation of 33 per cent of a tone, A.D. .07 and a rate of 5.8 oscillations per second.

Graphs of both control and final tones found in Fig. 17 were made from "time-line method" readings. This accounts for the smoothed appearance of the curves as compared with other graphs of the study.

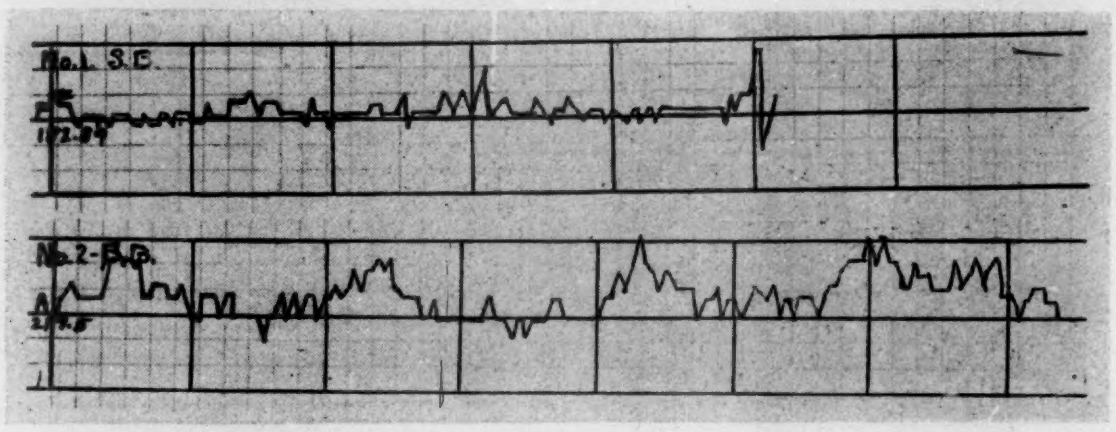

FIG. 18. Controlled tone and vibrato for S.B.

*Experiment No. 5-A: in training men vocal students to produce vibrato.* Only two *O*s are shown in this experiment, both of whom were regular vocal students of the writer.

Observer S.B., baritone, sang without vibrato as shown in graph No. 1, Fig. 18. After a training period of seventeen weeks, one instruction period a week, the *O*'s final tone photograph was taken showing a vibrato at the rate of 5.4 oscillations per second. He discontinued his course at the close of the semester so that the metronome technique for the increase in rate was not given him. See Table VI of Results, for further information in regard to the outcome of this experiment.

Observer W.O., tenor, a trumpet player, sang without vibrato as is shown in graph No. 1, Fig. 19. His first practice tone, graph No. 2, taken on the twelfth week of his training period—two instruction periods a week—shows an incipient vibrato.

Daily practice with the metronome during the remaining four weeks of his training period resulted, as shown in graph No. 3, Fig. 19, in a vibrato which measured 7.4 oscillations per second with an average extent of 25 per cent of a step. See Table VII.

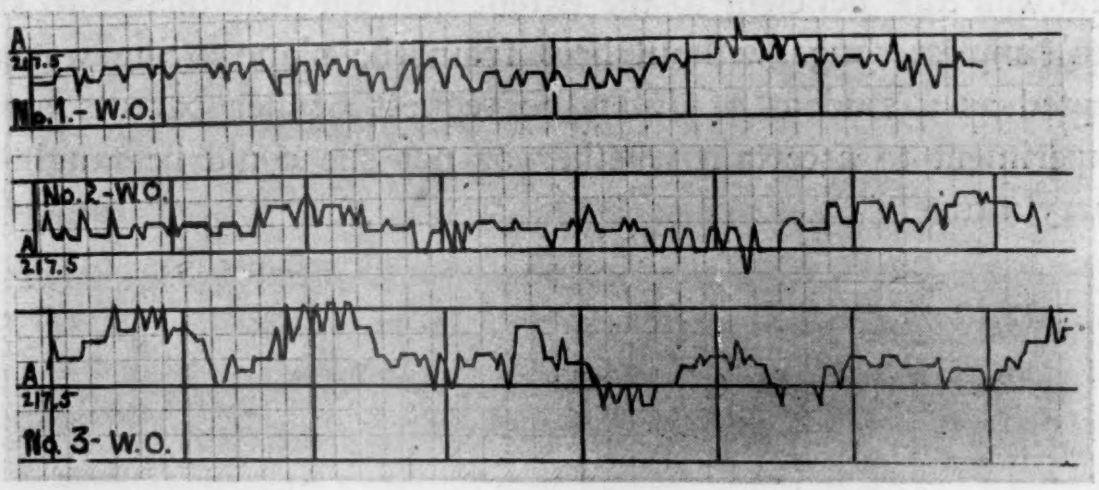


FIG. 19. Controlled tone, first practice tone and final tone for W.O.

*Experiment No. 5-B: in training women vocal students to produce vibrato.* Five *O*s took part in this experiment, four of whom cultivated vibratos and one who was unable to produce vibrato by the end of the eighteen weeks' training period.

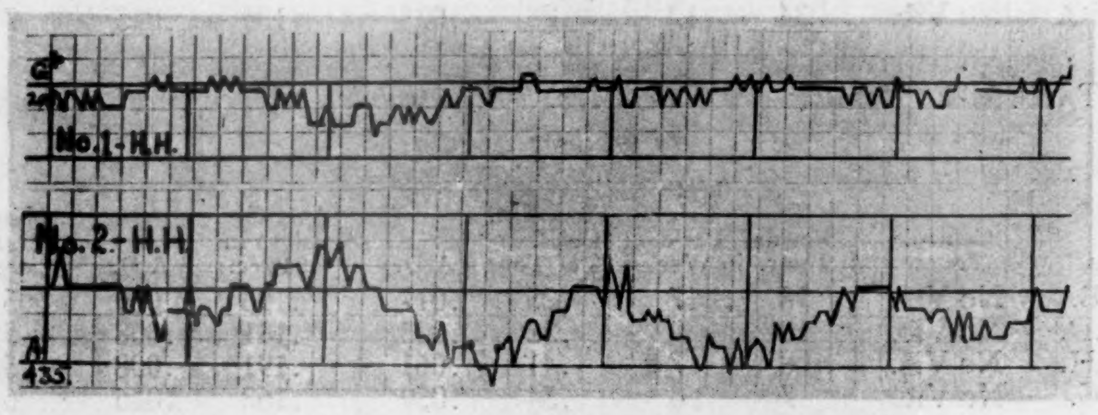


FIG. 20. Controlled tone and vibrato for H.H.

H.H., soprano, sang without vibrato as shown in graph No. 1, Fig. 20. By imitation of the "standard tones" of the various artists' records used in this study, and by practice of the technique outlined in Part II for the production of the vibrato, she was able on the seventh week of her training period—one instruction period a week—to produce the vibrato shown in Fig. 20, graph No. 2, the rate of which is 5.2 oscillations per second, with an

average extent in oscillation of 41 per cent of a tone. Consult Table VII for details and results.

H.W. was the only *O* in this experiment who within an eighteen weeks' training period was unable to produce vibrato. She was tone deficient to the extent that she was unable to sing the simplest songs without help from the piano. She was accepted as a student of *E* at the request of her parents as an experiment to ascertain whether or not she could be taught to carry a tune.

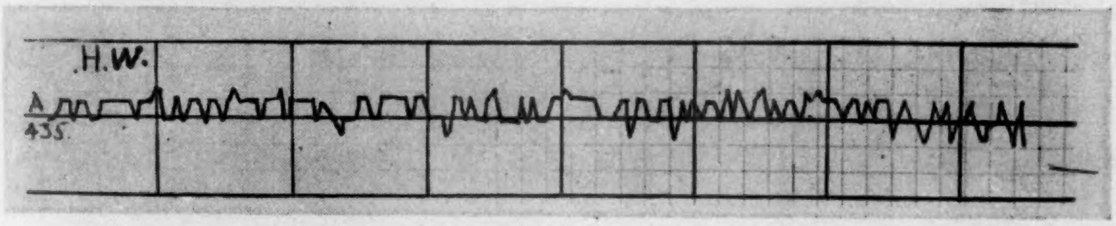


FIG. 21. Controlled tone for H. W.

TABLE VI. *Results: experiment No. 5-A in training men vocal students to produce vibrato*

| *Os* | Control Tones | No. Per'ds Instr. | L'gth Tr'g Per'd in Weeks | Final T. Ave. Ext. Oscil. in % of Tone | A.D. | Final T. Ave. Cyc. L'gth in .01 sec. | A.D. | Final T. Rate Oscil. per sec. |
|---|---|---|---|---|---|---|---|---|
| S.B. | No Vib. | 18 | 17 | .30 | .000 | .184 | .007 | 5.4 |
| W.O. | No Vib. | 34 | 17 | .25 | .075 | .135 | .013 | 7.4 |

TABLE VII. *Results: experiment No. 5-B in training women vocal students to produce vibrato*

| *Os* | Control Tones | No. Per'ds Instr. | L'gth Tr'g Per'd in Weeks | Ave. Ext. Oscil. in % of Tone | A.D. | Ave. Cyc. L'gth in .01 sec. | A.D. | Rate Oscil. per sec. |
|---|---|---|---|---|---|---|---|---|
| B.B. | No Vib. | 18 | 17 | .25 | .017 | .196 | .009 | 5.1 |
| M.D. | No Vib. | 10 | 9 | .22 | .023 | .181 | .008 | 5.5 |
| H.H. | No Vib. | 8 | 7 | .41 | .061 | .191 | .008 | 5.2 |
| R.G. | No Vib. | 7 | 6 | .34 | .059 | .162 | .016 | 6.2 |

*Experiment No. 6-A: case studies in increase in rate.* In order to include an example of a learning curve in each of the following main experiments in the teaching control of increase and decrease in rate and extent of vibrato oscillation, it was decided to carry out a final series of learning curve experiments. The procedure was to be essentially the same as with the main experiments which follow with the exception that the vocal practice was to be confined to half-hour instruction periods six days a week. Con-

trolled tones were to be taken at the beginning of each individual experiment; and practice tones were to be photographed as frequently thereafter as *E* felt that a change had been made. This made possible the construction of the proposed learning curves.[17]

In order to avoid question as to whether or not the training given would carry over into interpretative singing, the exercises, as with all other *O*s, were from the beginning applied to meaningful sentences and artistic song material.

*Experiment No. 6-A: showing a learning curve for increase in rate of vibrato oscillation.* The instructions given were the same as for the other adult *O*s described in Part II.[18] W.L. possessed a bass voice with a slow rate of vibrato. He was a violinist but had never had any vocal training. His control phonophotographs, for technical reasons, were a failure. His first practice phonophotographs, therefore, taken after the training had proceeded four days, were of necessity used as controlled tones. The first eight days of his training period were spent in learning to apply the "General Instructions" to intoned sentences expressing joyful emotion and to the singing of songs in English which moved at a quiet tempo. Special attention had to be given to the relaxation of the *O*'s jaw and neck muscles, the undue tension of which gave his voice a "throaty quality." From the ninth to the fourteenth day of his training, the first part of each instruction period was spent in listening to "standard tones" from the records of Chaliapin and Martinelli, and in "hand-fanning" to the vibrato of these artists' tones. The "hand-fanning and stepping exercise" was also used, with and without the metronome, while sustaining vowel sounds. Song singing formed part of every instruction period.

*O* reported that he believed that proper placement—"sensing the vibration in the front of the mouth"—shifting the responsibility of controlled expiration for singing from the chest to the abdominal muscles and learning to "feel" the vibrato in a subjective rhythm of fours were responsible for the improvement in

[17] The new strobo-photographic camera invented by *Metfessel* (**8**) was used in photographing the voices of the observers in this experiment.

[18] The four *O*s taking part in this series were graduate students in the department of psychology, University of Iowa.

his control of rate and regularity of oscillation. His final photograph taken on his twenty-eighth instruction period showed a rate of oscillation of 6.7 per second. See Table VIII for his rates and Fig. 22 for his learning curve.

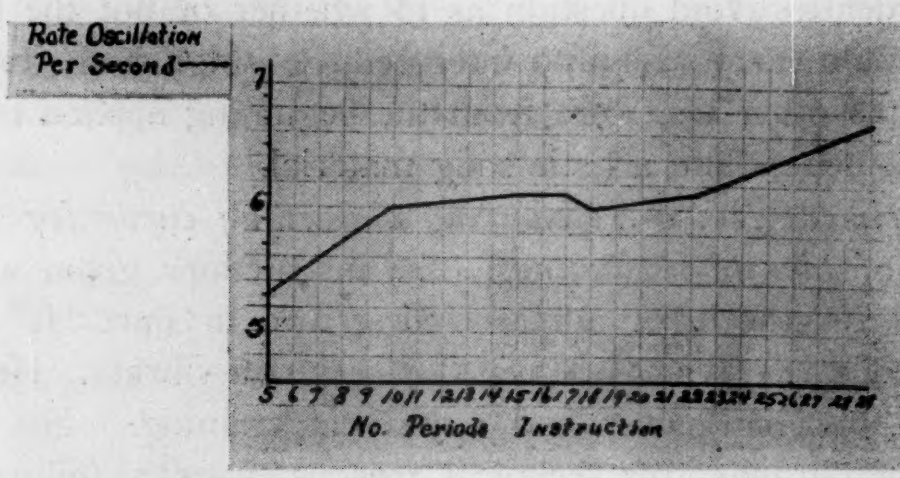


FIG. 22. The results shown in Table VIII.

TABLE VIII. *Results: experiment No. 6-A showing learning curve for increase in rate of vibrato oscillation. Observer W.L.*

| | | Ave. Vib. Cyc. L'gth in .01 sec. | A.D. | Rate of Oscil. per sec. |
|---|---|---|---|---|
| Con. Tone | 5th Instr. Per. | .191 | .014 | 5.3 |
| 1st Prac. T. | 10th " " | .168 | .012 | 6.0 |
| 2nd " " | 15th " " | .165 | .015 | 6.1 |
| 3rd " " | 16th " " | .164 | .021 | 6.1 |
| 4th " " | 17th " " | .163 | .028 | 6.1 |
| 5th " " | 18th " " | .166 | .014 | 6.0 |
| 6th " " | 27th " " | .165 | .010 | 6.1 |
| 7th " " | 29th " " | .150 | .014 | 6.7 |

*Experiment No. 6-B: showing learning curve for increase in rate of vibrato oscillation—Observer R.M.* Observer R.M., a baritone, had studied voice for one year. His controlled tones showed a rate of 4.8 oscillations per second. He sang with a tense jaw and reported that he experienced throat tightness while singing. He reported that he had always thought that his vibrato "was supposed to take care of itself." He was surprised to learn how much slower his rate was than that of the "standard tones" of the artists' records. He submitted to the routine of training readily enough, however, and was enthusiastic about the musical aspects of the experiment. On the second instruction period he was able to apply the "General Instructions" to the singing of

vowels, sentences, and a Handel aria. On this date he followed the metronome with his vibrato at met. 66, 69, and 72, choosing for this exercise a subjective rhythm of fours. On the third instruction period, he was able to follow the metronome at 80 and 84, sustaining vowels for one subjective measure of four, stopping on the next click of the metronome. He reported that the rhythm established by the metronome helped him to " crowd " the rate of oscillation of his vibrato, even after the clicking of the instrument had stopped. He also reported that in singing with the metronome, he was not necessarily conscious of rhythm unless the oscillation of his vibrato " lagged,"—did not synchronize with the clicks, in which case he felt a certain " urge "

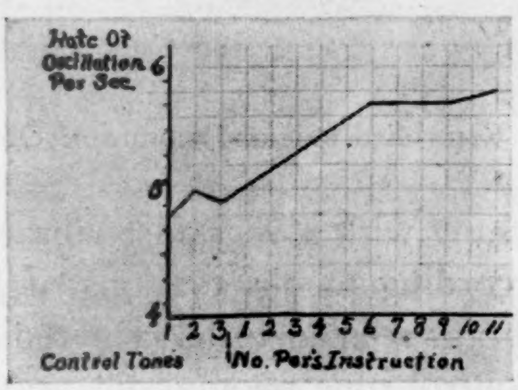


FIG. 23. Example of a learning curve showing increase in rate. Observer R.M.

to keep up. This " urge," he reported was kinæsthetic and seemed to come from tension in his abdominal musculature in the neighborhood of the diaphragm.

His final photograph taken on his eleventh instruction period shows a rate of 5.8 oscillations per second. See Table IX for results of his training and Fig. 24 for his learning curve.

TABLE IX. *Results: experiment No. 6-B showing learning curve for increase in rate of vibrato oscillation. Observer R.M.*

| | | Ave. Vib. Cyc. L'gth in .01 sec. | A.D. | Rate of Oscil. per sec. |
|---|---|---|---|---|
| 1st Con. Tone | 1st Day Exper. | .209 | .025 | 4.8 |
| 2nd " " | 2nd " " | .201 | .021 | 5.0 |
| 3rd " " | 3rd " " | .206 | .031 | 4.9 |
| 1st Prac. T. | 6th Inst. Per. | .176 | .027 | 5.7 |
| 2nd " " | 9th " " | .176 | .003 | 5.7 |
| 3rd " " | 11th " " | .173 | .010 | 5.8 |

*Experiment No. 7: in training vocal students to increase the rate of vibrato oscillation.* In this experiment the *O*s, with the exception of W.R.C. and M.S.S. (see Table X), were all regular vocal students of *E*. For plan of training and procedure see detailed description in Part II.

*Sample case histories and graphs of tones corrected.*

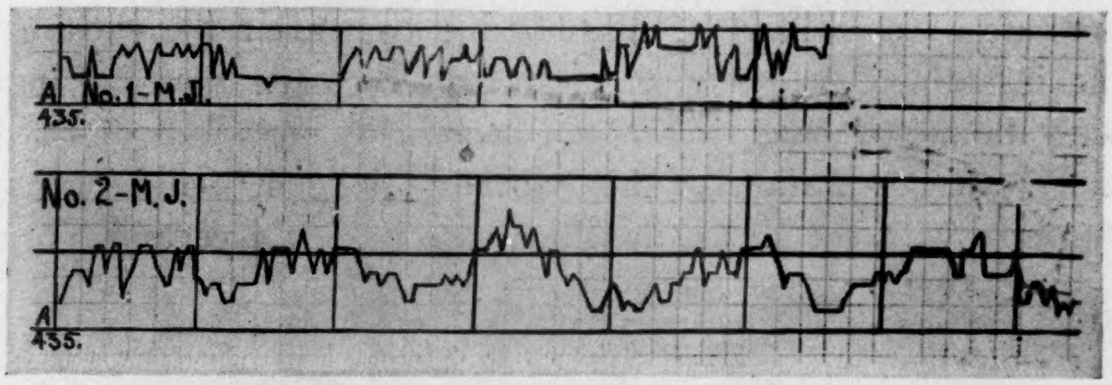


FIG. 24. Controlled tone and vibrato of Observer M.J.

M.J., soprano, sang with a very fast vibrato in a tone without much power. According to observations of both *O* and *E*, the control of the vibrato seemed to be centered in the throat. Unfortunately her control tone photograph proved to be a failure, owing to technical difficulties, and had to be retaken after *O* had been given the "warm breath device," described in Part II. Graph No. 1 of Fig. 24 shows her second controlled tone, using a slow diaphragmatically controlled vibrato having a rate of 4.8 oscillations per second. Graph No. 2, taken sixteen weeks later, shows her rate to be increased to 6.6 oscillations per second.[19] See Table X for details concerning her training and improvement.

M.M., soprano, sang with a "natural vibrato" and did not, at first, wish to become an *O* in the experiment. After studying one semester, however, she became interested to know her rate of oscillation, which, when tested with the metronome, showed under 6 oscillations per second. At *O*'s request, her voice was photographed at her next lesson period, showing a rate of 5.7 oscillations per second. One month later her final tone photo-

[19] In the graphs of Experiment No. 7 the increase in rate will be shown by the oscillations being drawn closer together.

graph showed a rate of 6.3 oscillations per second. See Fig. 25 for control and final tone graphs and Table X for details of training and improvement.

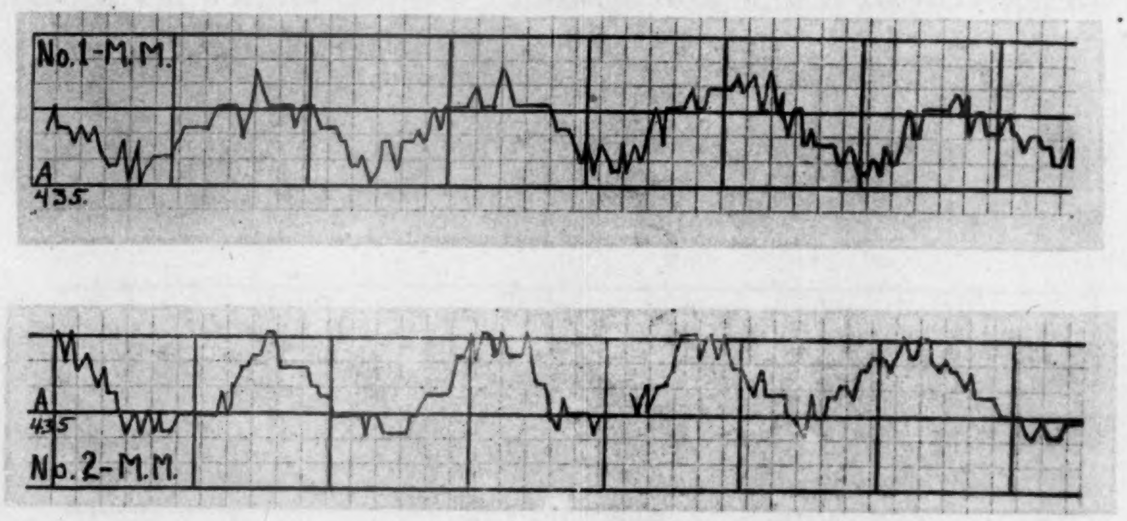


FIG. 25. Controlled tone and vibrato for Observer M.M.

L.W., contralto, had four instruction periods weekly and did comparatively little home practice during her eleven weeks' training period. An examination of her training record in Table X shows that the rate of her controlled tone was 5.6 and of her final tone 6.2 oscillations per second. Graph No. 2, Fig. 26, also shows marked improvement over No. 1 in regularity of vibrato oscillation.

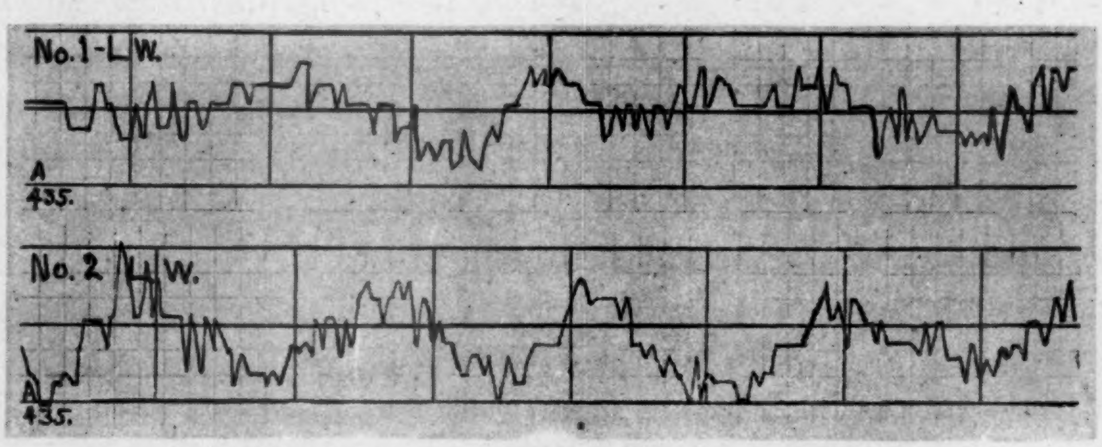


FIG. 26. Controlled tone and final tone for Observer L.W.

I.L., contralto, a professional radio singer, sang with a narrow extent of vibrato, shown in her control tone graph, Fig. 27, to be 19 per cent of a tone, with a rate of 5.9 oscillations per second. After a four weeks' training period she sang the first practice

tone of this series, shown in graph No. 2 to have an average extent of 63 per cent of a tone and a rate of 6.8 oscillations per second. Graph No. 3 of her final tone shows an average extent of 38 per cent of a tone and a rate of 6.8 oscillations per second.

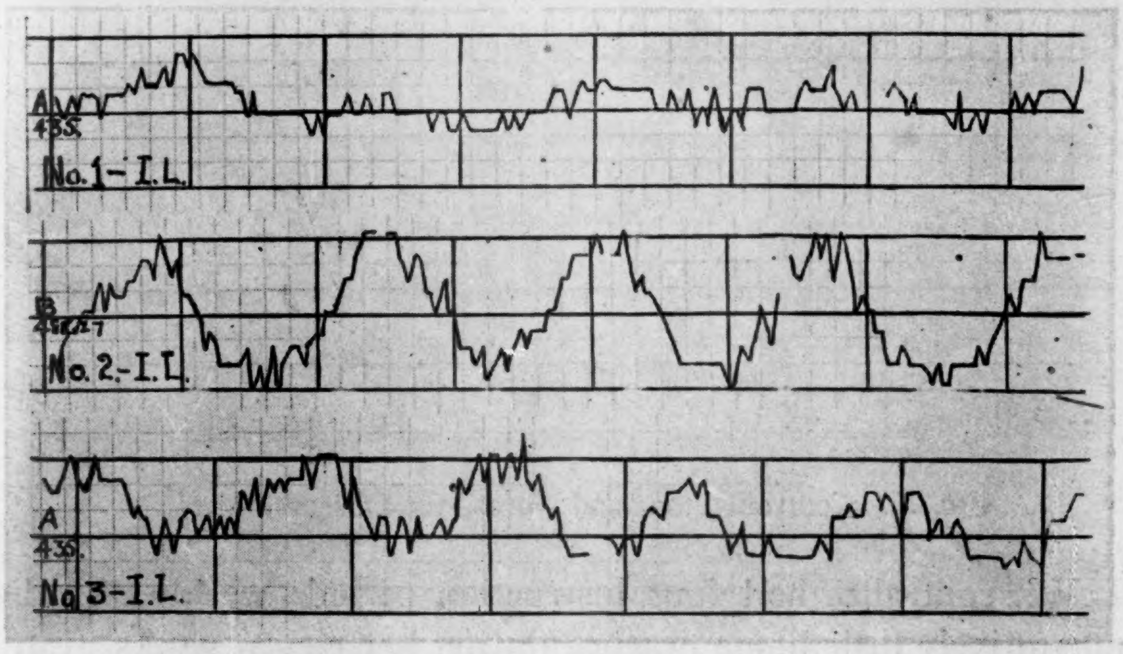


Fig. 27. Controlled tone, first practice tone and final tone for Observer I.L.

W.B.L., a vocal teacher, had a rate of vibrato oscillation which, measured by the metronome on *O*'s first instruction period, showed a range of from 4.3 to 4.9 oscillations per second. The

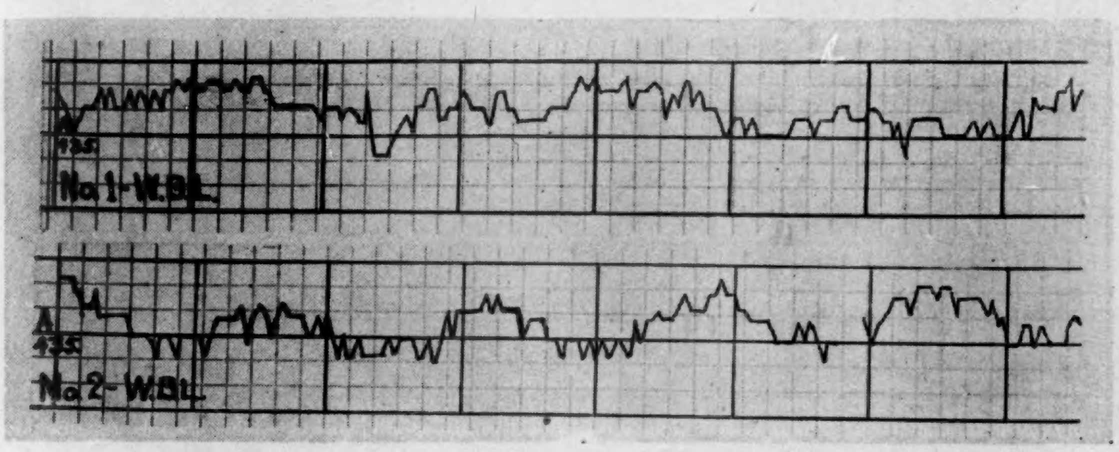


Fig. 28. Controlled tone and final tone for Observer W.B.L.

vibrato shown in his control tone, Fig. 28, was too irregular to be measured accurately as to rate, although the narrow extent of oscillation seemed to mitigate somewhat the effect upon the ear usually produced by so slow a rate. After four instructional

periods and practice extending over a training period of six weeks, his rate increased to 6.1 oscillations per second, photographed without aid of the metronome. (See Graph No. 2, Fig. 28, for improvement, also in regularity and extent of oscillation.)

TABLE X. *Results: experiment No. 7 in training vocal students to increase rate of vibrato oscillation*

| *Os* | No. Per'ds Instr. | L'gth Trg. Per'd in Weeks | Con. T. Ave. Cyc. L'gth in .01 sec. | A.D. | Rate Con. Tone | Ave. Cyc. L'gth Final Tone | A.D. | Rate Final Tone |
|---|---|---|---|---|---|---|---|---|
| W.R.C. | 4 | 3 | .191 | .002 | 5.2 | .177 | .012 | 5.6 |
| D.D. | 8 | 7 | .177 | .022 | 5.6 | .160 | .016 | 6.3 |
| F.F. | 9 | 4 | .179 | .024 | 5.6 | .162 | .011 | 6.2 |
| M.J. | 36 | 18 | .207 | .048 | 4.8 | .151 | .009 | 6.6 |
| R.K. | 10 | 2 | .164 | .011 | 6.1 | .153 | .013 | 6.5 |
| I.L. | 10 | 9 | .170 | .007 | 5.9 | .147 | .008 | 6.8 |
| M.M. | 8 | 4 | .175 | .002 | 5.7 | .159 | .004 | 6.3 |
| A.N. | 5 | 4 | .177 | .062 | 5.6 | .162 | .009 | 6.2 |
| W.P. | 6 | 5 | .200 | .002 | 5.0 | .184 | .013 | 5.4 |
| H.P. | 14 | 13 | .209 | .017 | 4.8 | .185 | .012 | 5.4 |
| M.S.S. | 2 | 7 | .203 | .021 | 4.9 | .185 | .001 | 5.4 |
| W.S. | 11 | 10 | .177 | .012 | 5.6 | .133 | .008 | 7.5 |
| M.S. | 4 | 3 | .197 | .011 | 5.1 | .159 | .012 | 6.3 |
| F.S. | 15 | 7 | .170 | .013 | 5.9 | .154 | .012 | 6.5 |
| L.W. | 46 | 11 | .179 | .054 | 5.6 | .164 | .006 | 6.1 |

*Experiment No. 8: showing a learning curve for decrease in rate of vibrato oscillation.* Observer R.L. On the completion of the eighteenth instructional period of Experiment No. 12, it was decided to use Observer R.L. in this experiment also for decrease in rate of vibrato oscillation. Reference to Table XI shows a slight increase in rate during the first part of the training period in Experiment No. 12 with a slight decrease toward the close. This dropping off in rate without attention to the function may have been brought about by the singing of quiet songs throughout the training period for decrease in extent by the æsthetic feeling for the appropriateness of a slower rate, suggested by the sentence used in photographing.[20]

The specific training for decrease in rate was introduced by listening again to the " standard tone " in the *Lucy Marsh* record, by " hand-fanning " synchronously with the artist's vibrato, and

[20] *O*'s extent of oscillation also continued to decrease until the close of the experiment for decrease in rate.

with the metronome set at 100 and at 96. For the latter exercise *O* chose a subjective rhythm of fours and reported little difficulty in following the metronome either with her hand or with her vibrato at these rates, although she was unable to sing with

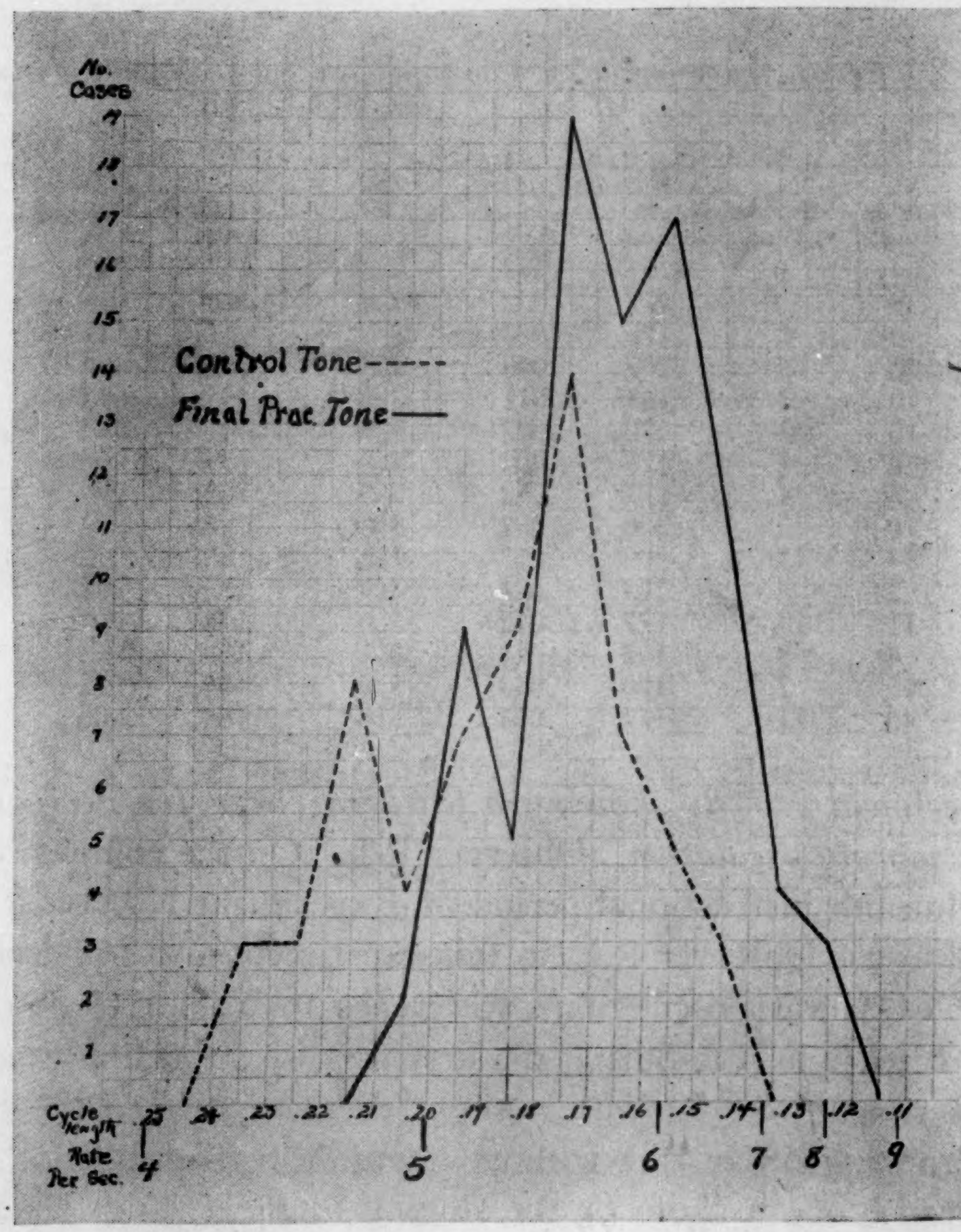


FIG. 29 shows graphically the improvement in rate of observers listed in Table X.

the metronome at 92 until the second lesson period. On the fifth instruction period, she was able to follow the metronome at 88 and 84 and on the eighth lesson day, at 80. Throughout this entire training period she sang only quiet songs and lullabies in English. She reported that the establishment of a slow subjec-

tive rhythm had "everything to do with the slowing down" of her rate. Her practice tone photographs taken on the eighteenth period of instruction showed a rate of 6.5 oscillations per second, while her final photograph showed a rate of 5.9 oscillations per second. See Table XI of results and Fig. 32 showing learning curve of this experiment.

TABLE XI. *Results: experiment No. 8 showing learning curve for decrease in rate of vibrato oscillation. Observer R.L.*

| Ave. Vib. Cyc. L'gth in .01 sec. | A.D. | Rate of Oscil. per sec. |
|---|---|---|
| .153 | .014 | 6.5 |
| .141 | .010 | 7.1 |
| .141 | .011 | 7.1 |
| .150 | .008 | 6.7 |
| .154 | .068 | 6.5 |
| .154 | .007 | 6.5 |
| .159 | .021 | 6.3 |
| .176 | .008 | 5.7 |
| .169 | .010 | 5.9 |

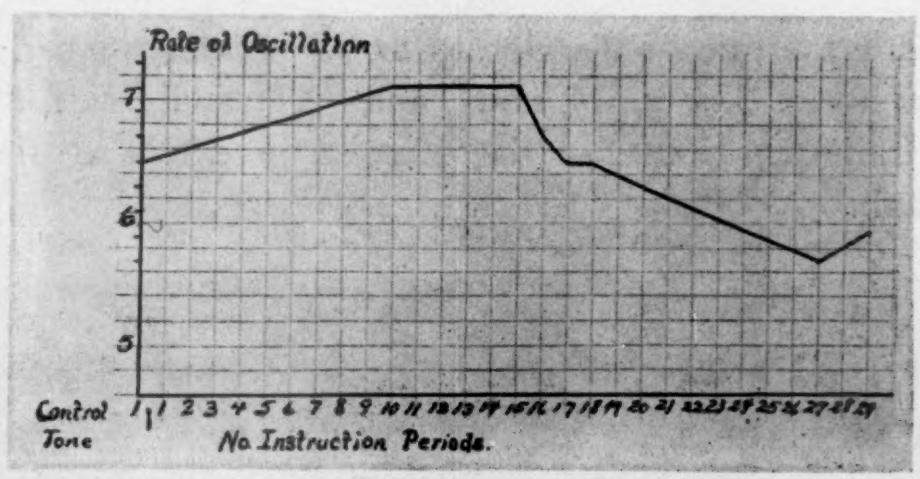


FIG. 30 shows graphically the results given in Table XI.

*Experiment No. 9: in training vocal students to decrease rate of vibrato oscillation.* In this experiment there were six *O*s, two of whom are not represented in Table XII owing to lack of success on the part of *E* to procure controlled tone photographs until after the corrective training was well under way.

Observer F.H., baritone, a German trained musician, sang with a continually fast rate and a wide extent of vibrato. See Fig. 31, No. 1, for graph of his controlled tone, the rate of which was 8.1 oscillations per second.

*O* reported that he had been taught to ignore the vibrato. He was much interested, as a musician, in the idea of controlling the rate of oscillation by means of rhythm. Through practice with his own metronome over a period of eight weeks, he was able

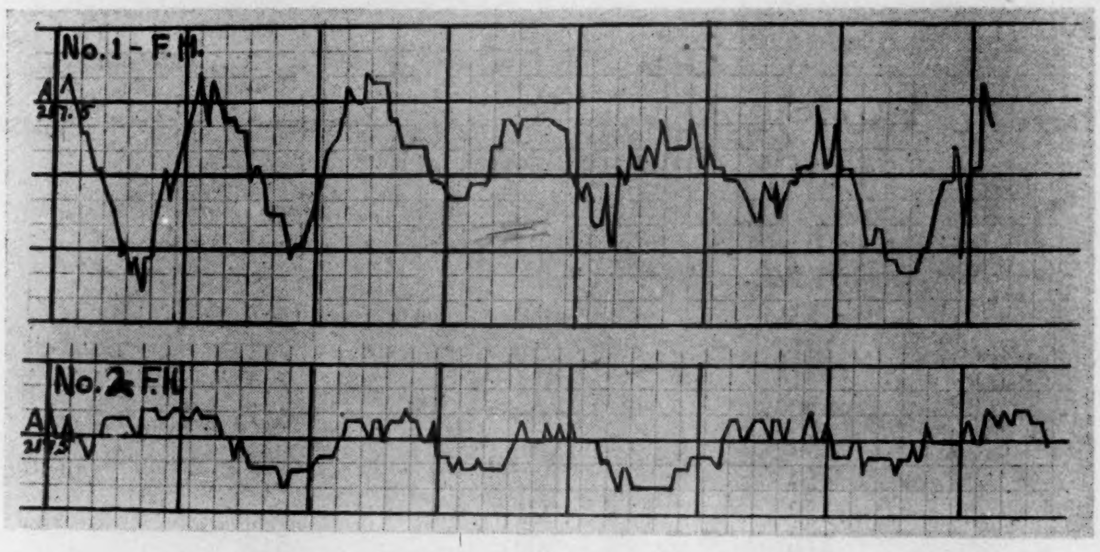


Fig. 31. Controlled tone and final tone for Observer F.H.

to decrease the rate of his vibrato to 6.5 oscillations per second. See Graph No. 2, Fig. 33, and Tables XII and XV for results of his training. Note also the decrease in extent as shown in this graph.

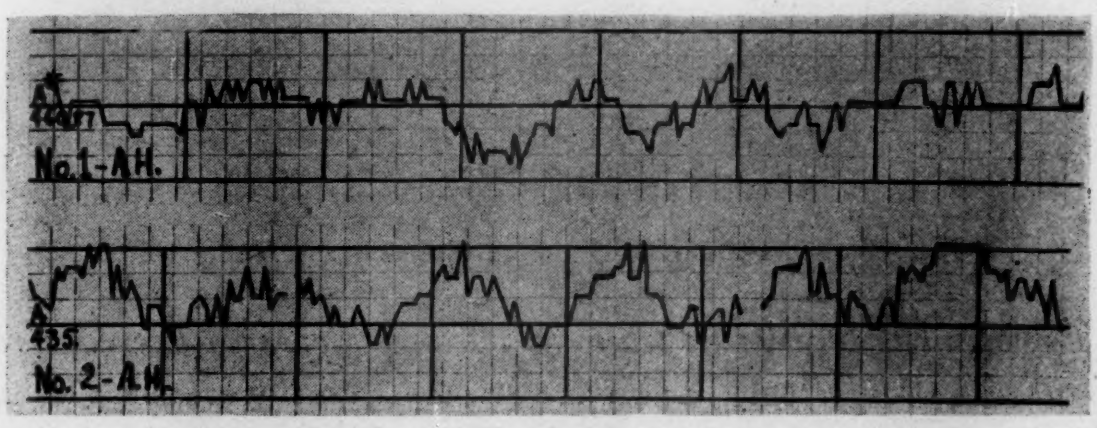


Fig. 32. Controlled tone and final tone for Observer A.H.

A.H., soprano, had studied voice about two years. According to observations of both *O* and *E*, she sang with a very fast "throat controlled" vibrato. Her controlled tone graph, Fig. 32, No. 1, shows a rate of 8.8 oscillations per second. After practice with the metronome while using the "warm breath device"

over a training period of seventeen weeks, she was able to sing her final tone without the metronome at a rate of 7.9 oscillations per second. See Fig. 32, No. 2, for graph of her final tone and Tables XII and XIV for records of her improvement in rate and extent of vibrato oscillation.

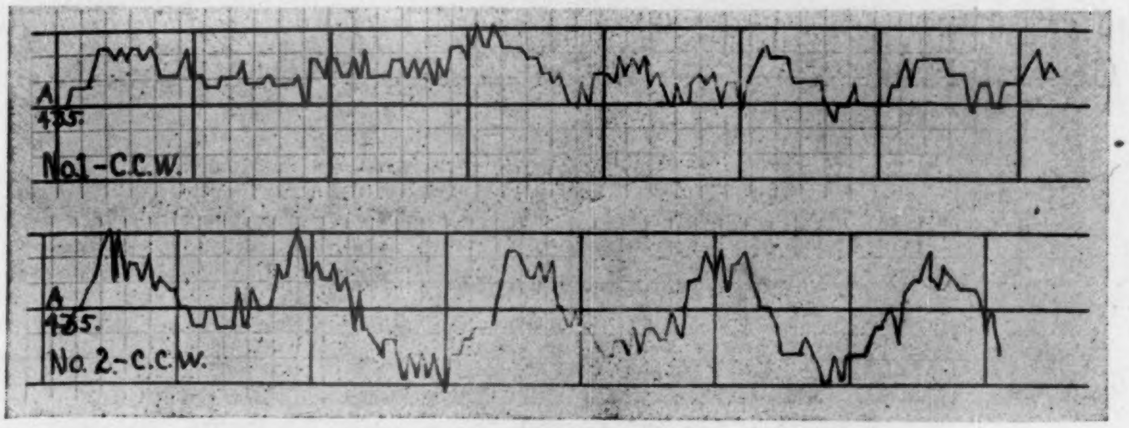


FIG. 33. Controlled tone and final tone for Observer C.C.W.

C.C.W., soprano, had a very fast throat controlled vibrato, shown in Fig. 33, No. 1, having a rate of 9.6 oscillations per second. After practicing with the metronome and using the "warm breath device" for a period of three weeks, her final tone graph, seen in Fig. 33, No. 2, shows a rate of 6.7 oscillations per second. See Tables XII and XIV for record and results of her training.

TABLE XII. *Results: experiment No. 9 in training vocal students to decrease rate of vibrato oscillation*

| *Os* | No. Per'ds Instr. | L'gth Trg. Per'd in Weeks | Con. T. Ave. Cyc. L'gth in .01 sec. | A.D. | Rate Con. Tone | Ave. Cyc. L'gth Prac. Tone | A.D. | Rate Final Tone |
|---|---|---|---|---|---|---|---|---|
| F.H. | 9 | 8 | .123 | .007 | 8.1 | .153 | .016 | 6.5 |
| A.H. | 34 | 17 | .114 | .011 | 8.8 | .126 | .008 | 7.9 |
| C.C.W. | 4 | 3 | .104 | .018 | 9.6 | .150 | .007 | 6.7 |
| J.H. | 11 | 5 | .130 | .015 | 7.7 | .137 | .006 | 7.3 |

*Experiment No. 10: showing learning curve for increase in extent of vibrato oscillation—Observer J.T.* J.T., a baritone, had never studied voice but had served as *O* in an experiment in the measurement of pitch control of the voice by use of the tonoscope and had received a high rating for singing in tune. His control photographs, taken on four successive days showed

a range of averages in extent of from 15 per cent to 20 per cent of a tone. He reported that his control of extent of vibrato oscillation seemed to be located in the muscles of his throat. His speaking voice was decidedly "throaty"; his singing voice was pure in quality but without depth or power. Although his interest was clearly more in the scientific than in the musical aspects of the experiment, his progress was rapid in learning to apply the "General Instructions" to the sustaining of vowel sounds, in-

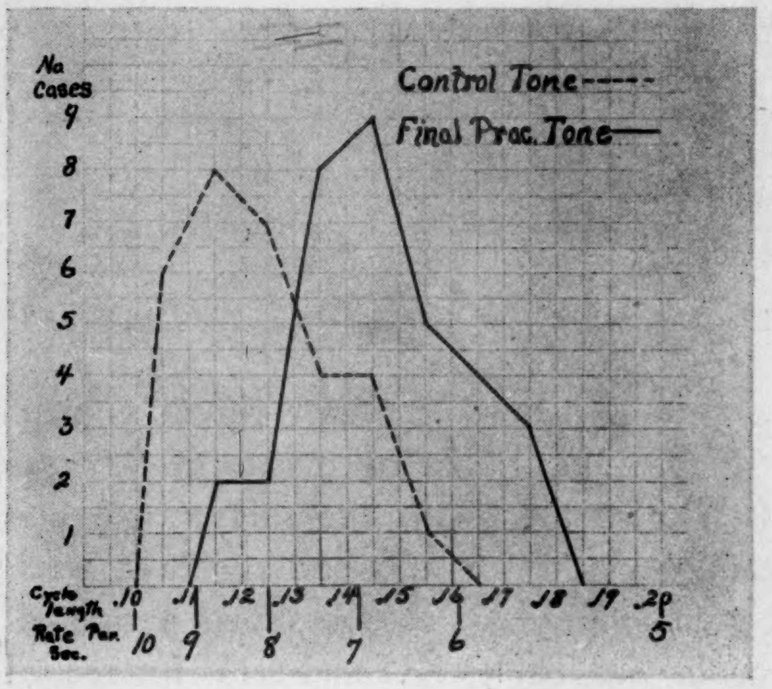


FIG. 34. The results given in Table XII.

toning of sentences expressing joyful emotion, and to the singing of virile songs. On the second practice period, *O* reported that his chief difficulty seemed to be to locate the abdominal musculature which operates in controlled expiration. This he was taught to do with the "warm breath device." On the following day, however, when a first pair of practice tones was attempted, his first efforts at singing with a diaphragmatically controlled extent were a failure; upon singing into the horn of the phonelescope, he reverted to his former habits and sang a throat controlled "head tone" which experience had taught him would produce a sine curve in the phonophotograph. It was only after the "warm breath device" had been reviewed that he was able to produce a tone that showed any increase in extent.

His final photographs taken on the seventeenth day of his training showed an average in extent of pitch oscillation of 33 per cent of a tone. See Table No. XIII for the results of his training.

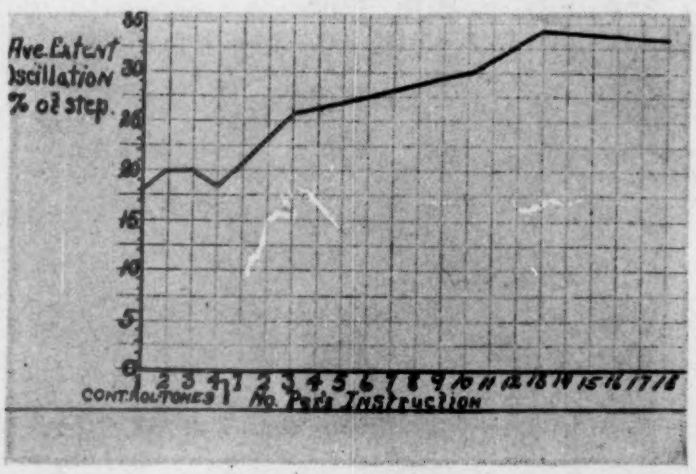

FIG. 35. The results given in Table XIII.

TABLE XIII. *Results: experiment No. 10 showing learning curve for increase in extent of vibrato oscillation—Observer J.T.*

| | | Ave. Ext. Oscil. in % of Step | A.D. |
|---|---|---|---|
| 1st Con. Tone | 1st Day Exper. | .18 | .030 |
| 2nd " " | 2nd " " | .20 | .030 |
| 3rd " " | 3rd " " | .20 | .020 |
| 4th " " | 4th " " | .19 | .013 |
| 1st Prac. T. | 3rd " " | .26 | .025 |
| 2nd " " | 10th " " | .30 | .054 |
| 3rd " " | 13th " " | .34 | .090 |
| 4th " " | 17th " " | .33 | .037 |

*Experiment No. 11: in training vocal students to increase extent oscillation of vibrato.* Nine *Os* took part in this experiment, all of whom were regular voice students of *E.*

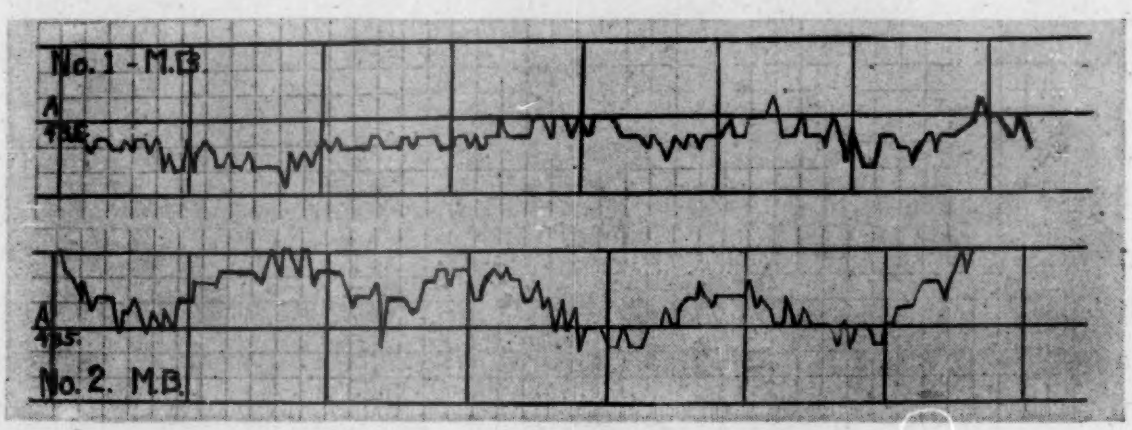


FIG. 36. Controlled tone and final tone of Observer M.B.

M.B., contralto, sang with a narrow extent of vibrato, shown in her control tone to be 13 per cent of a tone. After a seven weeks' training period during which she received thirteen periods of instruction, her final tone graph, Fig. 36, No. 2, shows an average extent of 25 per cent of a tone. See Table XIV for results.

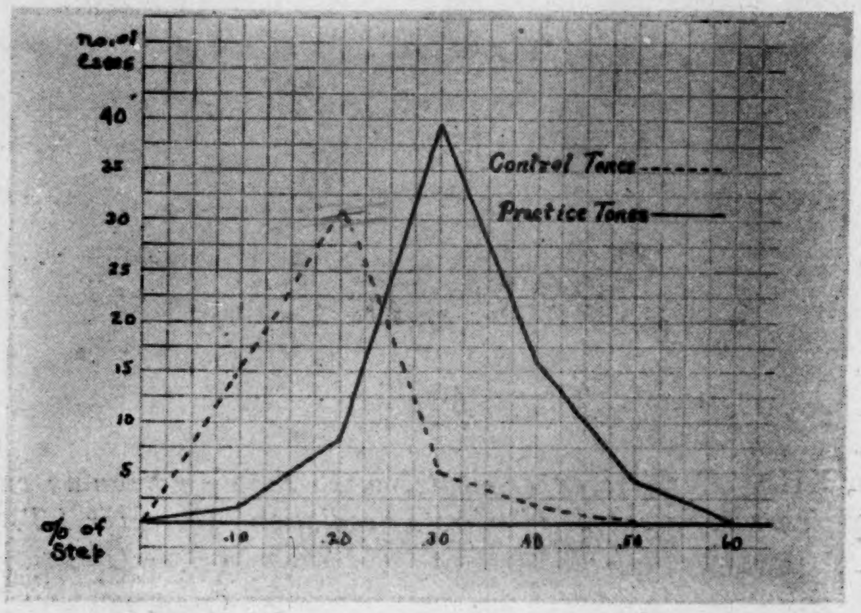


FIG. 37. The results shown in Table XIV.

TABLE XIV. *Results: experiment No. 11 in training vocal students to increase extent of pitch oscillation of vibrato*

| *Os* | No. Per'ds Instr. | L'gth Trg. Per'd in Weeks | Ave. Ext. Con. Tone % Tone | A.D. | Ave. Ext. Final Tone % Tone | A.D. |
|---|---|---|---|---|---|---|
| M.B. | 13 | 6 | .13 | .043 | .25 | .051 |
| A.H. | 34 | 17 | .25 | .050 | .35 | .018 |
| M.J. | 36 | 18 | .19 | .038 | .35 | .016 |
| I.L. | 10 | 9 | .19 | .040 | .63 | .047 |
| W.P. | 6 | 5 | .15 | .050 | .41 | .032 |
| F.S. | 15 | 7 | .26 | .052 | .35 | .043 |
| W.S. | 11 | 10 | .19 | .045 | .24 | .073 |
| C.C.W. | 4 | 3 | .21 | .032 | .40 | .075 |
| L.W. | 46 | 11 | .27 | .073 | .38 | .050 |

*Experiment No. 12: showing a learning curve for decrease in extent of vibrato oscillation.* R.L., soprano, had studied voice approximately one and one-half years. The vibrato in her two controlled tone photographs, taken on the day before training began, showed an average in extent of oscillation of 51 per cent of a tone; while the rates of oscillation shown in the two tones were 6.5 per second. She reported on the first day of training

that she had never exercised any conscious control over either the rate or the extent of her vibrato oscillation and did not believe that it could be done. Training for decrease in extent of oscillation was decided on for her first experiment, which was introduced by listening to the " standard tones " from the record of *Lucy Marsh.*

The first nine days of her training period were consumed in correcting the action of her lips, tongue and " breathing muscle," all of which were habituated to behave in a manner contrary to the " General Instructions " in Part II. On the tenth day of her training she was able to apply this newly acquired technique with some degree of success to the singing of quiet songs in English. She reported at this time that the " warm breath device," described in the " General Instructions," was most helpful to her in learning to locate the so-called " breathing muscle " and other muscles which operate in controlled expiration; also that her fist held tightly just below the sternum called her attention to excessive pulsations of the " breathing muscle," and helped her to steady the tone. The final photographs taken on the twenty-ninth instruction period showed an average in extent of oscillation reduced to 15 per cent of a tone in the two tones photographed. The vowel used throughout this series was " oo " in " cool," in the sentence, " The night is calm and cool." See Table XV for a detailed record of results and Fig. 42, showing the learning curve for this experiment

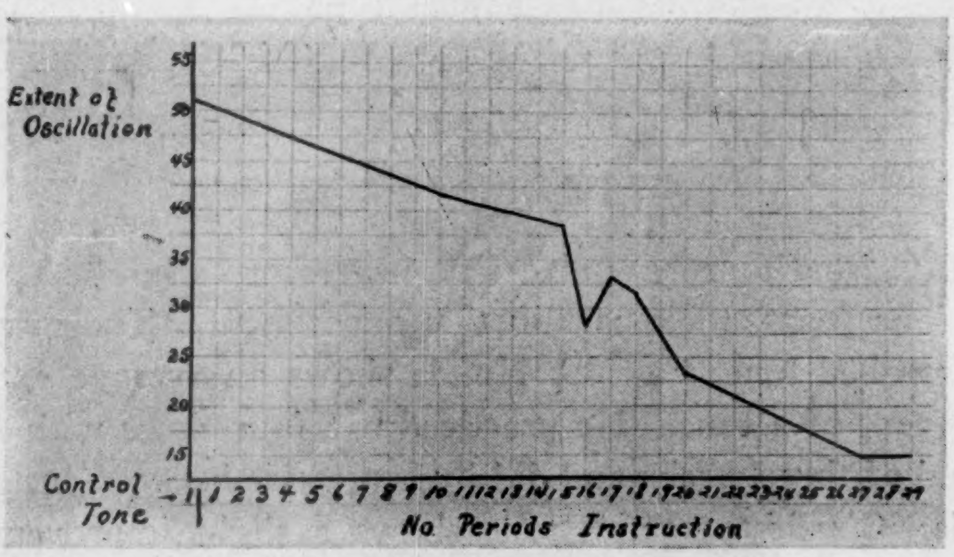


FIG. 38. The results shown in Table XV.

TABLE XV. *Results: experiment No. 12 showing learning curve for decrease in extent of vibrato oscillation—Observer R.L.*

| | | Ave. Ext. Oscil. in % of Step | A.D. |
|---|---|---|---|
| Con. T. | 1st Day Exper. | .51 | .068 |
| 1st Prac. T. | 10th Instr. Per. | .42 | .012 |
| 2nd " " | 15th " " | .38 | .013 |
| 3rd " " | 16th " " | .28 | .086 |
| 4th " " | 17th " " | .33 | .034 |
| 5th " " | 18th " " | .32 | .036 |
| 6th " " | 20th " " | .23 | .048 |
| 7th " " | 27th " " | .15 | .040 |
| 8th " " | 29th " " | .15 | .020 |

*Experiment No. 13: in training vocal students to decrease extent of vibrato oscillation.* Eight of the eleven *O*s who took part in this experiment were regularly enrolled vocal students of *E.*

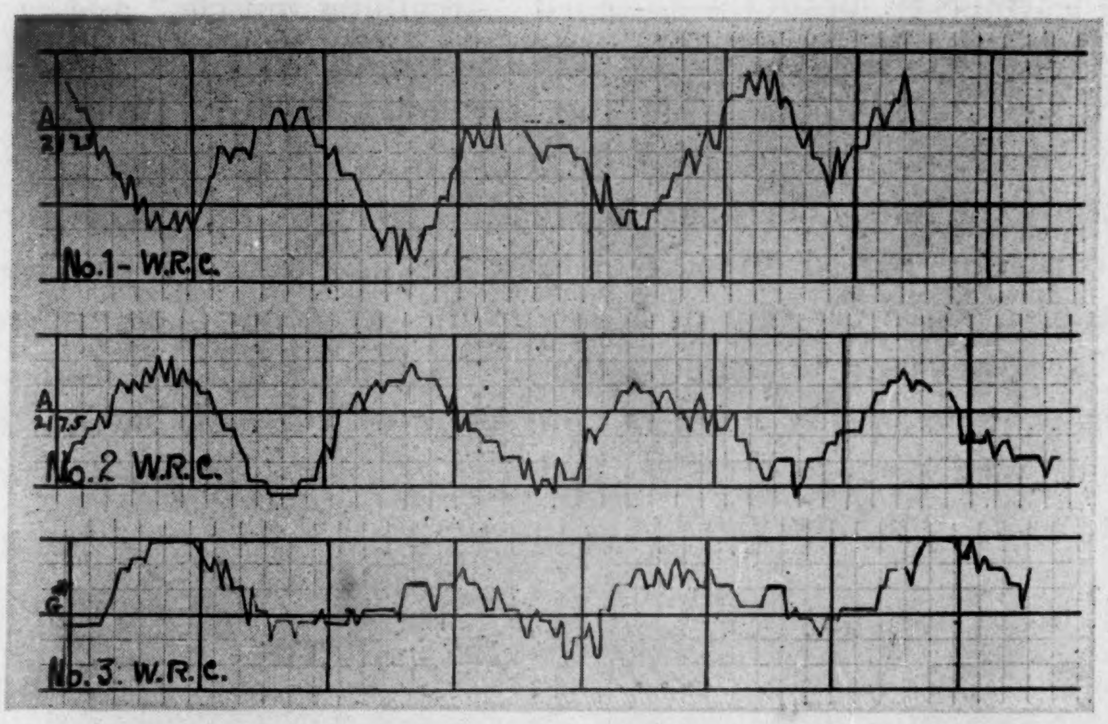


FIG. 39. Controlled tone, first practice tone and final tone for Observer W.R.C.

W.R.C., baritone, a university professor, who had studied voice four years, took part in this experiment. The graphs of his controlled tone, Fig. 39, No. 1, shows an average extent of 50 per cent of a tone. He practiced but four times with *E* over a period of three weeks and did little practice between instruction periods. *O*'s first practice tone shows a slight improvement in extent over his control tone. His final tone, however, given in

Fig. 39, No. 3, shows an average extent reduced to 32 per cent of a tone. See Table XVI for a detailed record of his training.

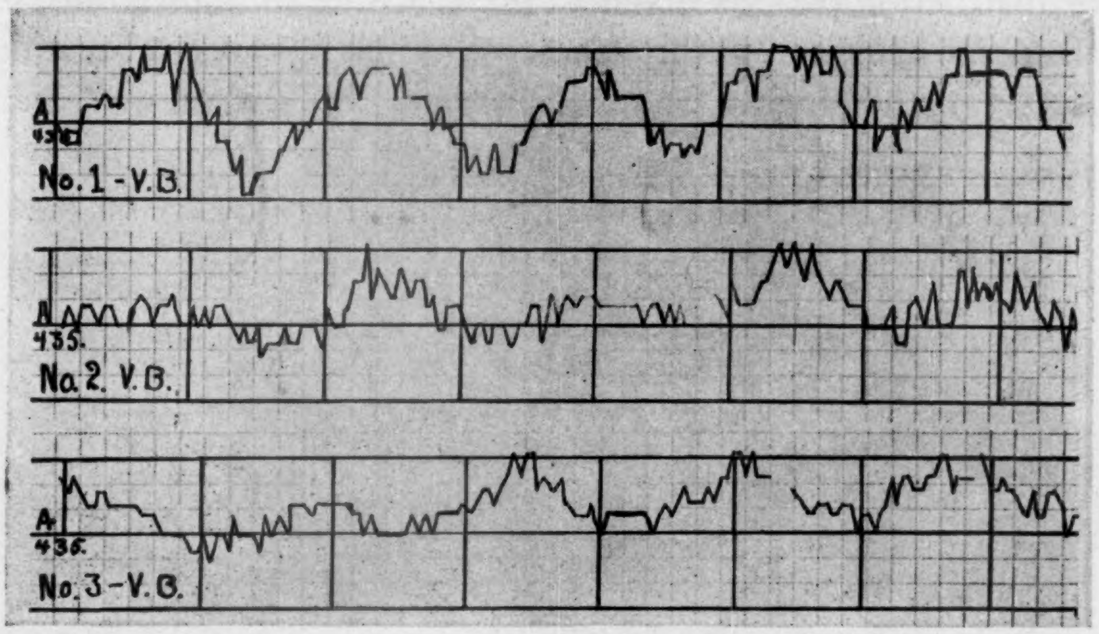


FIG. 40. Controlled tone, first practice tone and final tone for Observer V.B.

V.B., soprano, had studied voice about eight years. Her controlled tone showed an average extent in oscillation of 43 per cent of a tone. After eight periods of instruction, extending over a

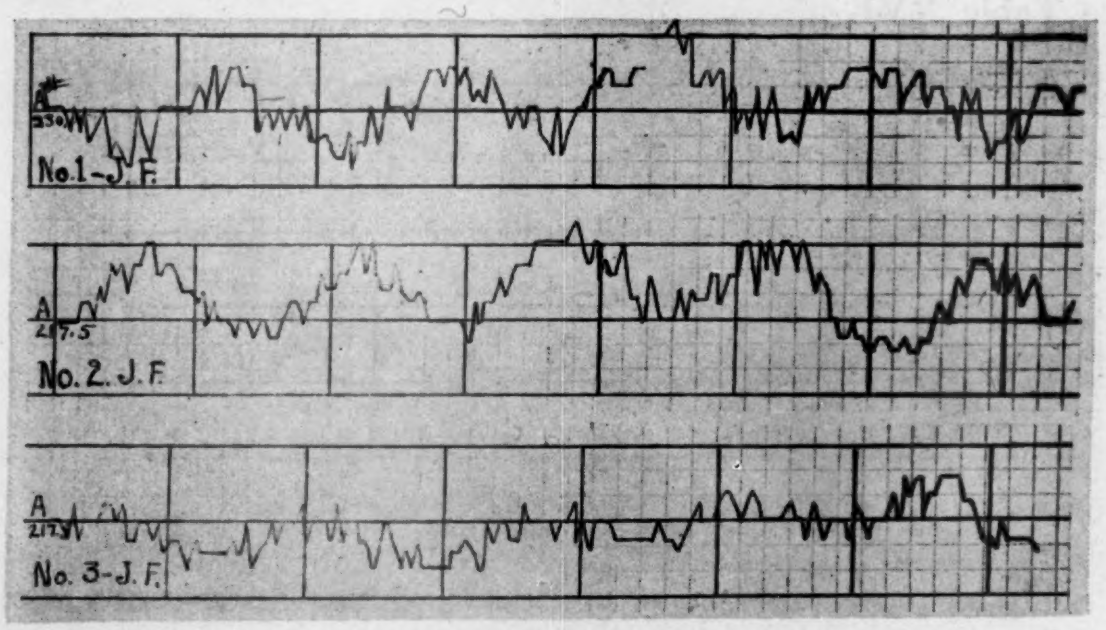


FIG. 41. Controlled tone, first practice tone and final tone for Observer J.F.

training period of seven weeks, her final tone—see Fig. 40, No. 3—shows an average extent of 25 per cent of a tone. See Table XVI of results for further details.

J.F., a professional baritone singer, shows in his controlled tone graph an average extent of 40 per cent of a tone. After four instruction periods given to the coaching of a program, but with special attention to the steadiness of the so-called " breathing muscle " in the singing of quiet passages, his extent was found

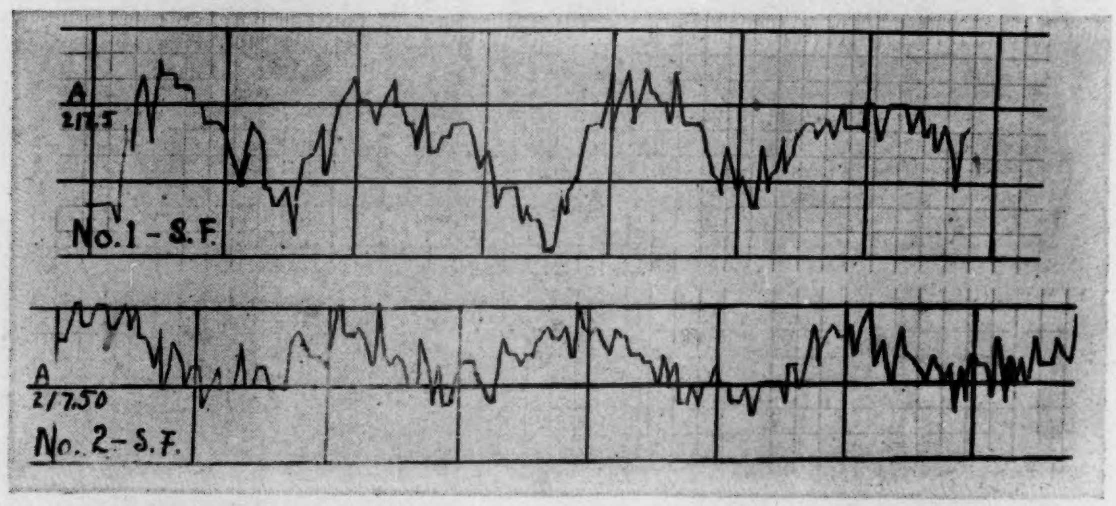


FIG. 42. Controlled tone and final tone for Observer S.F.

to be reduced slightly in his first practice tone. After eleven instruction periods, the end of his four weeks' training period, his final tone shows an average extent of 22 per cent of a tone. See Table XVI.

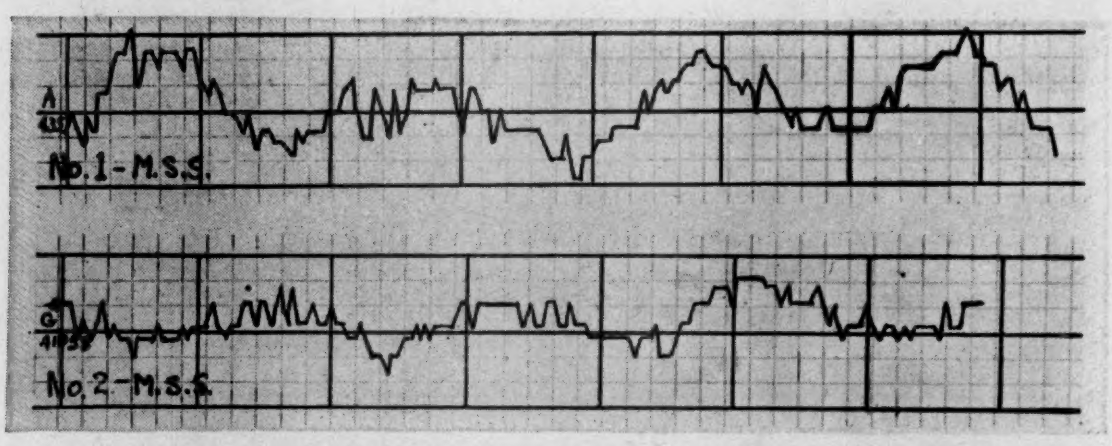


FIG. 43. Controlled tone and final tone for Observer M.S.S.

S.F., baritone, university professor, shows an average extent in his controlled tone graph, Fig. 42, No. 1, of 58 per cent of a tone. After five instruction periods extending over a training period of seven weeks, the graph of his final tone, see Fig. 42, No. 2, shows the extent decreased to 35 per cent of a tone. See Table XVI for complete results of his training.

M.S.S., a professional musician, showed in her controlled tone an average extent of oscillation of 39 per cent of a tone. After two periods of instruction, given seven weeks apart, her final tone, see Fig. 43, No. 2, shows 23 per cent of a tone. (See Table XVI.)

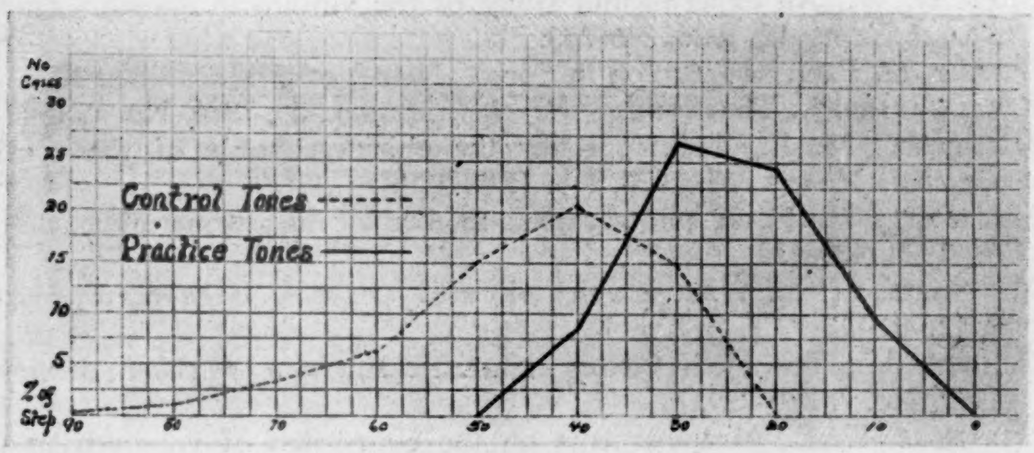


Fig. 44. Results shown in Table XVI.

Table XVI. *Results: experiment No. 13 in training vocal students to decrease extent of pitch oscillation of vibrato*

| *Os* | No. Per'ds Instr. | L'gth Trg. Per'd in Weeks | Ave. Ext. Con. Tone % Step | A.D. | Ave. Ext. Prac. Tone % Step | A.D. |
|---|---|---|---|---|---|---|
| V.B. | 7 | 6 | .43 | .056 | .25 | .017 |
| W.R.C. | 4 | 3 | .50 | .083 | .32 | .076 |
| D.D. | 8 | 7 | .51 | .037 | .31 | .089 |
| S.F. | 5 | 7 | .58 | .083 | .35 | .000 |
| J.F. | 9 | 4 | .40 | .066 | .22 | .033 |
| J.H. | 11 | 5 | .40 | .049 | .33 | .057 |
| F.H. | 9 | 8 | .61 | .131 | .30 | .025 |
| H.P. | 14 | 13 | .42 | .044 | .28 | .073 |
| M.S.S. | 2 | 7 | .39 | .045 | .23 | .057 |
| M.S. | 4 | 3 | .34 | .037 | .17 | .031 |
| I.S. | 26 | 13 | .40 | .000 | .29 | .048 |

### *Summary of Conclusions*

Conclusions drawn from the results of this study follow:

1. Refinements in control of the rate of vibrato oscillations can be effected through the influence of rhythm.

2. Refinements in control of the extent of vibrato oscillation can be learned through paying special attention to the action of the musculature having to do with controlled expiration, until correct habits of control are formed.

3. Both children and adults can be taught to sing with vibrato.

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